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School of Natural Resources

FLASHFIRE II: Simulated Fire Control Planning Under Uncertainty

By

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A report to the North Central Forest Experiment Station on Cooperative Research conducted by the School of Natural Resources, University of Michigan, from June 1972 to June 1973.

1973

ACKNOWLEDGMENTS

I wish to express my appreciation to William Bentley and Vaughn Frick for developing the first Flash Fire Simulation and providing endless assistance and encouragement in the building of FLASHFIRE II. I also owe a debt of gratitude to the following:

John Crosby, William Main, Von Johnson, Robert Loomis, and Pete Rossopoulis of the North Central Forest Experiment Station Fire Laboratory, East Lansing Michigan for their advice and assistance in modeling the fire relationships.

The North Central Forest Experiment Station, St. Paul, Minnesota, for the financial support that made the project possible.

John Carow for his comments and careful reading ot this report.

David Countryman and Scott Dickson of the SNAFOR Project, University of Michigan, Ann Arbor, for their assistance with gaming and programming.

And finally, thanks and acknowledgment go to Alfred Maley for preparing A Guide to FLASHFIRE and writing the functions IT, GAM, and GAUSS used to support the computer model; and to Mr. Maley and Mr. Frick for writing the subroutine REPLY used to handle the decision inputs into the program.

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Introduction

FLASHFIRE II is a management simulation game in which a computerized model is used to teach and provide practice in fire control and prevention planning. The model is a stochastic representation of the relationships between fire planning strategy and fire occurrence phenomena on a hypothetical forest protection area in the Eastern United States. Players may be resource management students who wish to master conceptual views or professional fire control personnel who wish to improve their strategic considerations.

FLASHFIRE originally was developed by Vaughn Frick and William Bentley (1971), School of Natural Resources, The University of Michigan with the cooperation and support of the National Science Foundation and the U. S. Department of Agriculture, Forest Service. The game stimulated interest from the Forest Service and further development was funded along lines suggested by the North Central Forest Experiment Station Fire Laboratory, East Lansing, Michigan.

The objective is to incorporate Forest Service damage appraisal techniques in an improved information format so that the player can visualize the effects of his strategy. Various basic relationships are illustrated so the player can respond to the information and improve his strategy. The game provides a low-risk atmosphere for the player to learn and practice his abilities in fire prevention and control planning. The internal structure of the game is designed to be easily altered by a programmer to incorporate different efficiency and geographical characteristics. These alterations may become necessary due to improved knowledge or the desire to represent a particular area or situation.

Purpose of the FLASHFIRE Exercise

The primary purpose of the exercise is to produce a device that provides insight into the stochastic phenomenon of wildfire. Managers and planners must face problems requiring decisions based on evaluation of probabilistic outcomes. The device, a simulation game, creates this situation and is intended to create such problems for the player to solve.

The reason for using a simulation game is to provide an effective means for teaching basic fire relationships and planning under uncertainty. The lesson is learned by experience gained at the computer terminal in a few minutes instead of on the ground in a few years. Further, the experience is provided at no risk to the "real world."

The development of such a simulation provides insight into the interactions of the natural phenomenon for both the player and the model builder. The model builder must visualize and quantify the interactions of the system. This quantification, per se, may be only an approximation, but the formulation requires in depth analysis. Further research can strengthen the realism of the model by providing more accurate and precise coefficients and state variables, but the identification of the variables was an exercise in itself. Constructing the model with this in mind can provide the modeler with an understanding of the information requirements of the planning system.

Simulation and Simulation Games

A computer simulation provides a dynamic environment and an extremely rapid time frame. The speed allows the simulation of weeks and years in a

few minutes of real time. The compression of time provides valuable experience in time related reactions that would take years in real world situations (Bare, 1971). The player has the opportunity to observe results and to test new strategies which would normally take many years to see in the real world. The simulation also provides the "low risk" atmosphere where a few seconds of computer time are traded for the risk of money and property.

The use of the computer is also effective because students seem to adopt the terminal as a communication link with some "real world" and begin playing very seriously. Most players are not computer oriented and have had little experience with such simulations. There seems to be a belief that the results are true born in the mysterious electronic machine creating a real life situation . Not all people get "in" to the role and truly learn from the experience, but a majority apparently do. Of the sixteen teams (four to six persons per team) observed playing as a part of an undergraduate resource management class, three fourths were able to project themselves into the role of fire control planner and successfully improve their strategy. Similar results were established through a formal questionnaire used for about 200 undergraduates playing the first version of FLASHFIRE in 1972 (Bentley, 1972).

In order to accomplish the realism and rapport necessary to teach the principles, the game required several features:

First, a mathematical model of the prevention and presuppression relationships and effects to fire size/occurrence. The resulting fire-years must be mathematically realistic in the eyes of players with a variety of backgrounds.

Second, the results of the strategy must be visible to the player. With random events, the results must be drastic enough to be visible through the variability and yet not so drastic that the realistic variation is no longer a factor. This information must be presented to the player in such a way that he can deduce what has happened. Players will use this information as feedback in revising strategy in search of the optimum.

Third, the simulated fire year must be balanced in such a way that it is not so difficult that the player abandons the task and yet not so easy that he loses interest for lack of challenge. This balance must exist for players of different backgrounds and levels of experience if it is to be effective in training people with the diverse interests of resource managers.

Fourth, a payoff is required to let the player know how he is doing and to provide incentives. There may be both positive and negative reinforcement from payoffs. These can be programmed into the game to congratulate good play and criticize poor play. Another approach could be for the instructor to provide some payoff for the person or team who achieved the lowest average cost-plus-loss.

To summarize, the important requirement of the simulation game is that the player believes what he sees and learns from it. The results may not be exactly true to the real world, but in this case being close is often good enough. It can be considered a case where the "ends justify the means."

Conceptual Review of Fire Planning

There are several possible objectives that the planner may choose for his fire prevention and control strategy: minimize the number of fires, minimize the size of fires, minimize property damage due to fire, minimize

his prevention/presuppression/suppression budget, minimize fire damage to socially or politically sensitive areas, or some combination of these. The classical approach has been to use the least-cost-plus-loss approach (Davis, 1959; Davis and Storey, 1969; Streeby, 1969). This efficiency criteria has been built into FLASHFIRE so the objective of the player is to minimize the value of his prevention and presuppression budget plus suppression costs plus property damages. To accomplish this, he searches for an optimum mix of tactics that will prevent fires, reduce average fire size, and to concentrate his resources in areas of sufficient value to justify the expenditures.

A means of identifying these areas of importance is by establishing a dollar value at risk (Streeby, 1969) or value protected (Crosby, 1973) for reasonably homogeneous strata in the protection area. The value at risk should be an accurate evaluation of the potential value lost, replacement value, or any possible economic effect of a wildfire occurrence in the area. Note that the fire could possibly produce a net benefit (Crosby, 1973). The value at risk is a function of a number of ecological and economic factors. For example, a ground fire in a white oak stand will probably do little damage and can even accelerate tree growth while a fire of the same intensity in a young white pine stand can cause 100% mortality resulting in value lost in growth plus the cost of site preparation and replanting. In another case, a destructive fire on a scenic slope with watershed importance will result in loss of the value to replace the cover plus the unquantifiable loss to the people who enjoyed viewing the area. The cost of watershed improvement and soil stabilization can be added to the

value at risk. By having this information about his protection area, the planner can formulate a strategy to match expenditure level to value protected.

The approach to minimizing cost-plus-loss has three phases: prevention, presuppression, and suppression (Davis, 1959). Prevention includes the various means of reducing the number of fire starts in an area. Presuppression actions are those that set up the suppression organization in an attempt to minimize the size of fires that do start. Suppression is the action taken to control fires once started. This is one factor that cannot be exactly budgeted for; nor can the damage resulting from fire. Cost-plus-loss includes the budget for prevention and presuppression plus the cost of suppressing the fire plus the property value lost in the fire.

The values considered fall into two categories. The first is the budget, this is the prevention and presuppression cost that the planner incurs to pay for his strategy. The second is the value associated with fire, cost of suppressing the fire plus the property value lost. The expenditures in the first category are used to minimize the value of the second. To minimize the sum of these two, a careful balance must be found. For example, a $500,000 budget might result in a $200,000 suppression plus property damage value. But the optimal least-cost-plus-loss might be $400,000 in budget resulting in $250,000 suppression plus property damage value. In economic terms, there is a point where the marginal return is exceeded by the marginal investment. For example, an additional dollar invested in fire prevention would only return a ninety cent reduction in

suppression plus property damage . At this point, one cannot justify the additional dollar in terms of least-cost-plus-loss.

In planning for the year, the player must take into account the possibility of overbudgeting as well as not spending enough. But this problem is deeper than the above discussion. One can note that some values, the scenic slope for example, are difficult or impossible to quantify. The replacement value is of assistance, but these values must be carefully considered in a qualitative manner to justify the level of protection used.

Wildfire: A Random Event

Fire occurrence in nature is a function of a multitude of factors, most of which are random in time and space. For example, fire size and occurrence may be strongly affected by weather. But, we cannot predict with certainty whether the coming year will be wet, dry, windy, or characterized by frequent lightning storms. We cannot effectively control such factors, but we can at least describe them in terms of probability distributions. The phenomenon of wildfire has several such distributions associated with it. Two in particular are used in the FLASHFIRE model:

The first distribution describes the number of fires that will occur in a given year in a given area. Various factors including weather, fuel condition, and prevention tactics employed will cause some years of numerous fires, some of few fires, and over many years will generate a frequency distribution having a "hump" around the mean and "tails" describing the variability. The mean is the "expected number of fires" and the variability describes the probability of extreme good or bad years.

Second, the size of the fire will also follow a probability distribution. The random events affecting the distribution include weather, topography, fuels, discovery time, suppression time, and other uncertainties. For any one fire, the combination of these things will be different and their interaction generally unpredictable. Unpredictable with deterministic certainty that is: we can establish probable bounds and describe probable behavior within those bounds. Given a constant suppression factor, the fire size subject to the interactions can be described by a frequency distribution. The shape of the distribution would characterize the sum of all of the random effects on fire size.

Fire size and number of fires are two of the most important distributions with which the planner must deal. A third, the distribution describing the occurrence of fire starts in time is of importance but has not been included in the model. This distribution would require the exercise of building a time-series model. Since the purpose here is to provide a one-year-at-a-time model, the distribution in time is of less importance and was not included.

Role of the Fire Planner

Given the random nature of wildfire size and numbers, the role of the planner becomes one of a manipulator of distributions. He has two basic approaches to the task of minimizing cost-plus-loss: stop fires from occurring and minimize the size of the ones that do occur. For example, by scheduling a series of radio announcements, the planner is not certain that they will prevent thirty fires in an area, but he expects that the 100 expected fires

in the area will be reduced by 30%. It would be possible to treat the effectiveness of various fire prevention measures as random events and associate probability distributions with various geographic areas.

Classification of areas by prevention effectiveness has been done in the game. The ten strata are areas of homogeneous probability of fire start. This can be projected to the real world situation where a planner can stratify his protection area by fire occurrence probability. Because of flaws in the assumption of homogeneous probability, lines and points (called blocks in the game) were established and a higher probability of fire associated with them. These represent roads, dumps, railroads, and any other discrepancies in the assumption of homogeneous probability. The strata and blocks form a spatial pattern of fire probability with which the planner must deal. This is an important consideration in the assignment of resources to prevention activities and presuppression establishments.

Establishing the probabilities for such a pattern in the real world would present difficulties. For example, it would be difficult to establish the probability of fire starting for a given level of billboard coverage and radio coverage because we seldom find a situation which has been static for sufficient time to gather enough data. Further, effectiveness of a single prevention tactic is difficult to establish because the situation of all but one tactic held constant over sufficient time to determine the effect of the varying tactic is seldom found. This may exclude the use of empirically derived relative relationships, but logically derived relationships may be sufficient. For example, one can deduce that radio announcements will have greater effect on fire probability near a highway where people are listening

to car radios than along a railroad where the fires are started by hot box and engine sparks.

The effect of manipulating the distributions can be illustrated with frequency distribution plots, Figure 1. The solid line represents the initial probability density function. When the prevention program is implemented, the curve is shifted left indicating a smaller expected number of fires (dotted line). Figure 2 illustrates the possible effect of establishing a fire station on the fire size distribution. Establishing a station nearby causes the curve to shift left indicating a smaller average fire size and a thinner tail indicating less chance of a larger fire occurring (dotted line).

The possibilities of "good" and "bad" fire years can also be illustrated by figures 1 and 2. The thickness of the right-hand "tail" of the distribution represents the probability of a "bad" year. When one is planning for the next year, these characteristics are very important. For example, the coming year is going to be "bad" but the planner budgets $350,000 for an expected "good" year (prevention plus presuppression costs). The results could be a year with $750,000 in suppression costs and damages. Had he budgeted $500,000 for a "bad" year, he might have held suppression costs and damages to $400,000. The result is a $1,000,000 cost plus loss instead of a possible $900,000 if he had planned for a bad year. Note that this is the opposite situation to that illustrated on page 6. There is no simple solution to this problem because there always is a possibility of a "bad" year. All that the planner can do is try for the long run least-cost-plus-loss and understand that bad years can happen. An alternative is to

Fire Occurrence Distribution

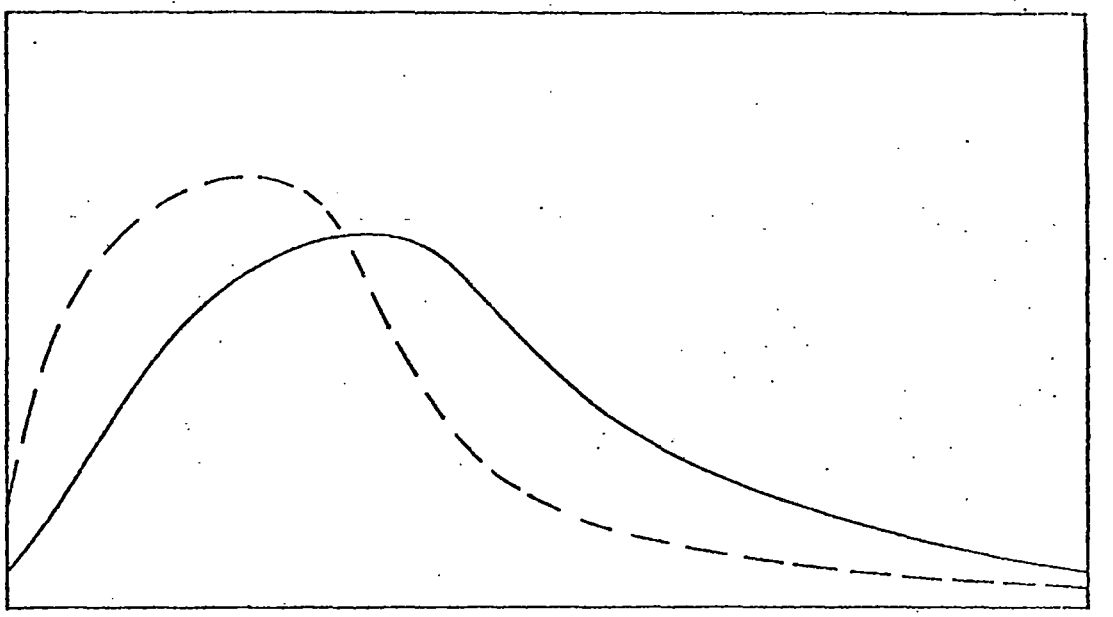

Figure 1

Fire Size Distribution

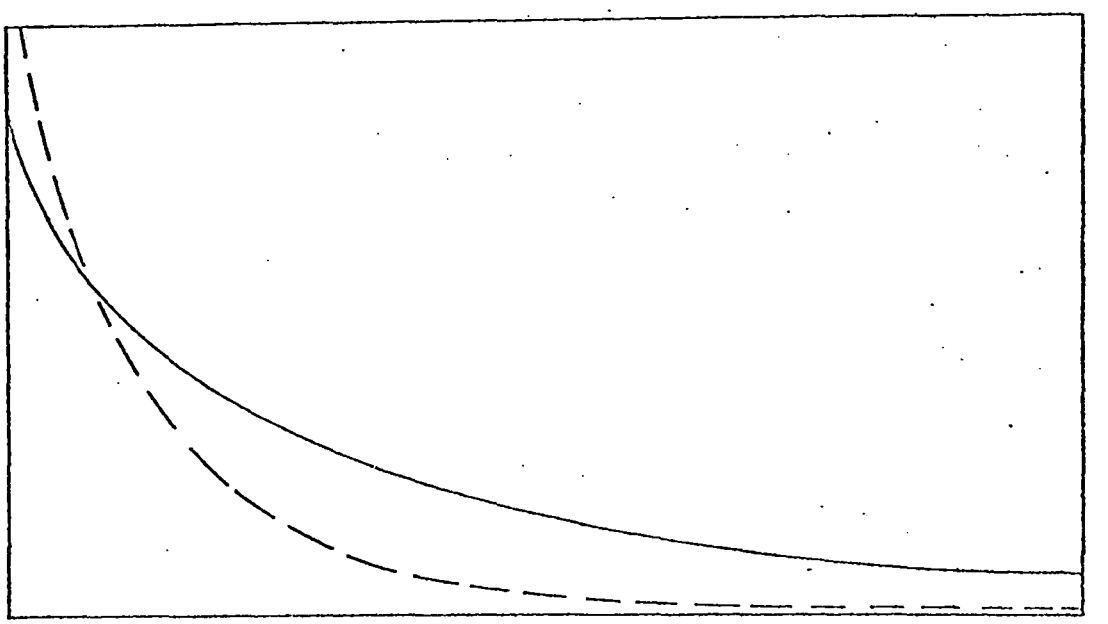

Figure 2

spend all that you possibly can and attempt to minimize the probability of a bad year at the expense of the least-cost-plus-loss criteria.

The Model

The model is a mathematical representation of the relationship between presuppression/prevention strategy and the fire size/occurrence phenomena. The model has been programmed into a computer to facilitate instantaneous evaluation of strategy inputs. The program approximates the relationship in such a manner that it will run efficiently and economically. This allows repeated runs of the game in short periods of time and at very low cost. For example, using the Michigan Terminal System IBM 360 computer, five years can be simulated, including the time required to input and output the strategy, in approximately one hour at a cost of $2.00. Since the response is instantaneous, most of the elapsed time is spent typing in the strategy and evaluating the output.

The random nature of the fire size occurrence phenomenon is simulated by describing them with randomly generated numbers. These random numbers are taken from approximations of frequency distributions. The player's strategy affects the expected number of fires and the expected fire size. On areas where the strategy is effective, the expected size and number are reduced and the variation is lowered. The actual outcome is random, but it is less likely to be as severe as if the strategy had not been implemented. The large fires and the very bad years are less probable following the implementation of a strategy, but they still may occur.

The model has an individual effectiveness function for each of the fire prevention inputs. These functions are incorporated into a matrix in such

a way that a programmer may introduce changes without restructuring the program. For example, if one were to discover that billboards were effective in reducing fire starts along a highway by a factor of 57%, changing one element in the matrix would be all that is necessary. Further, all of the information describing the hypothetical district is stored in data matrices at the beginning of the program where it can be easily altered. The only internal function of interest is the fire station effectiveness equation. This simple linear equation may be replaced with any for which one has superior empirical or theoretical support.

The model has a fixed set of prevention and presuppression tactics available to the player. The following is a listing and description of them:

1. Billboards: visual public information devices including "Smokey Bear" signs, fire danger indicators, and various other means of preventing fires in publicly traveled areas.
2. Public Information Contacts: a series of scheduled public meetings, conducted by trained personnel, designed to educate groups, such as Boy Scouts and camping clubs, about the dangers of using fire in the forest.
3. Radio Announcements: a series of scheduled radio "spots" to inform motorists, campers, and residents of fire danger. (Remember only you can prevent forest fires.)
4. Fuel Modification: the modification of hazardous fuels by controlled burning or mechanical crushing (or chopping).

5. Fire Breaks: a one chain strip of bare earth along both sides of a right of way (railroad or highway) or around a dump or camp, intended to prevent fire start and spread from areas of known fire start potential. The cost includes maintaining the equipment to plow the breaks three or four times a year and to pay a crew to brush the breaks at least once a year.

The rest of this list includes tactics of the presuppression type:

6. Fire Stations: a fully manned and equipped station with one pumper, located by players choice, and maintained for a required five years.
7. Value at Risk Survey: a professionally prepared investigation into the actual value at risk due to wildfire in each of the homogeneous strata in the district.
8. Fire History: a short p. . graph describing some of the areas of bad fire history and implying some magnitudes of slash acreage and numbers of fires.

The following along with 7. and 8. above are the information outputs available from the game, they are to be used as a presuppression tactic or feedback to revise the year's strategy:

9. Summary Table: a summary of the year's suppression cost plus property damages by strata and by fire size class. The table also includes the number of fires in each strata, total number of fires, average fire size, and total cost-plus-loss for the year.

10. Details of Fires: an optional output of the coordinates, suppression cost plus property damage, and acreage of individual fires in a strata and size class. This does not include cause of the fire.

11. Projected Averages: an optional evaluation of a strategy by averaging over a ten year period using a Monte-Carlo simulation. This is used to unmask the strategy from the random variation.

SCENARIO: The Beaver Belly District

The player has just been assigned as Fire Protection and Prevention Officer of the newly formed 2500 square mile Beaver Belly Forest District (See Map, Appendix I). Previously, the area had been protected by the inadequate efforts of the Bellyville volunteer fire department and various logging and railroad crews that chanced to be working in the area. Now, through the formation of a government owned "forest" (or a privately owned "corporate forest"), a decision has been made to provide intensive fire protection for the district. The volunteers, logging crews, and railroad crews will still be available for project fires and multi-fire emergencies, but government and private funds have been made available to use for the bulk of the work. The F.P. and P. Officer is charged with setting up a prevention and presuppression plan, to be revised yearly, for the district. (Depending on the group needs, a year's run with no strategy may be given to the players to represent information on the effectiveness of the previous protection efforts.)

The Beaver Belly is generally forested type, but there are some areas of agriculture and residential use. Route 2, a highway of heavy summer use crosses the district from East to West. The Beaver Belly & Buffalo Chip Railroad traverses the district from North to South going over the Western slopes of the Beaverhead Mountain. There are both hardwood and softwood logging operators in the area. The district is divided into ten strata to represent several more or less homogeneous value at risk and fire start pattern situations. Ten blocks, comprised of lines or small groups of cells[1/], have been added to represent discontinuities in the otherwise homogeneous fire start patterns. The general characteristics of the strata and blocks are as follows:

Stratum 1: Row crop and pasture woodland; short discovery time because of farmers present in the fields.

Stratum 2: Oak-hickory forest; some furniture grade sawtimber being logged; some recreational use for hunting and hiking; long discovery time because of fewer people in the woods and obstructed lines of sight.

Stratum 3: Grain and pasture agriculture; short discovery time because of farmers present in the fields.

Stratum 4: High value residential subdivision (Goldenview Subdivision) with homes interspersed with woodlots and brushy fields; watered lawns protect it from fire starts along Route 2; short discovery time due to people frequenting the area.

[1/] A cell is a one quarter square mile map grid unit.

Stratum 5: Farm town (Bellyville) with some forested parks and lots; fires discovered quickly and fought by the Bellyville Volunteers.

Stratum 6: Open unused brush area on slopes of Beaverhead Mountain; dry hazardous fuels available; the area is a fire problem because of a combination of dry brush, sparks from the dump, children from the subdivision, and cigarettes form passersby on Route 2 at the bottom of the slope. Note that although the land has little property value in terms of timber or development, there is value at risk to replace the cover for erosion and scenic reasons. It is also the watershed that supplies drinking water to the Goldenview Subdivision in Stratum 4. Because of open cutbanks, few fires spread from the railroad into this stratum.

Stratum 7: White and Scotch pine forest with logging and some pasture woodland activities; logging leaves between 500 and 1000 acres of slash per year; a fire problem because of long discovery time and large amounts of hazardous fuel. The area is commercially managed for timber production and most stands are mature at this time.

Stratum 8: White and Scotch pine forest, younger than stratum 7 and with a good deal of plantation acreage on old cutting areas and reclaimed farm land; long discovery time due to low population and obstructed view. Note that the per acre investment is higher than Stratum 7 because of the plantations and intensive management.

Stratum 9: Mixed hardwood forest with some furniture grade sawtimber but no logging; the recreation center for the district containing several summer homes and a large Girl Scout camp; a problem area because of recreational fire use and careless attitudes.

Stratum 10: Lowland cedar and tamarack type, usually wet but will dry hazardously during dry spells; some logging for poles and mine timbers along with heavy recreational use for hunting and trapping; long discovery time because of low population and obstructed view.

Blocks 11 to 15: Railroad, blocks 12 and 13, are on the slopes of Beaverhead Mountain and have long grades.

Block 16: Girl Scout Camp Moahottwatta, characterized by frequent campfire "escapes."

Blocks 17 to 19: Route 2, four lane highway used heavily in the summer.

Block 20: Dump, characterized by frequent burning permit violations.

In general, the area has an average of 25 inches of rainfall per year. There are occasional dry spring fire seasons and regular hot dry summer seasons. The district has averaged 100 fires per season with a cost-plus-loss ranging from $1,500,000 to $2,500,000. The railroad uses diesel engines in tandem and makes four runs a day, every six hours. Burned or crushed areas tend to brush in by the time that the next dry season occurs and fire breaks must be maintained intensively.

Play of the Game

This is a general description of play, details of the input and control of the game may be found in the Player's Manual, Appendix I.

The game is played at a terminal on line with a computer. The response to typed in commands and requests for information are immediate. Errors will result in diagnostic messages so the player need not have any knowledge of the program or programming in general. Once the instructor or demonstrator has readied the program, the following sequence takes place (for an example see Appendix VI):

Step 1: Using the map (Appendix I) and the initial information, the player formulates a strategy and types it into the computer via the terminal. All entries are made in plain language. To prevent fires, the player selects a combination and levels of the prevention tactics outlined previously. To control fires, the player may locate fire stations by grid coordinates found on the map.

Step 2: At the command "go", the computer simulates a year's fires and outputs a summary table at the terminal. Following the table, some comment is usually printed out to provide either positive or negative reenforcement for the player. This comment is a function of the cost-plus-loss of the year's fires. The comment cutoff points can be reset by the instructor (Appendix I) or he may use the values contained in the program.

Step 3: The player may now improve his information by requesting further details concerning the individual fires or a Monte Carlo evaluation of his strategy. The Monte Carlo evaluation must be purchased from funds allocated to next year's budget.

Step 4: Using the summary table and the additional information, the player corrects his strategy to improve his total cost-plus-loss value. This is a response to feedback as well as fire management exercise at this point.

Step 5: The player may continue this process for from four to five years, or longer, seeking the optimum combination that will minimize his cost-plus-loss. The repetition is necessary for the player to see the random variation in the model. A strategy that appears to be good may have been the result of a good year instead of good strategy. A good year would be one of heavier rainfall and fewer chance fire starts. After a few runs or a Monte Carlo evaluation, a poor strategy should become apparent. The player does have the option of running the same strategy for a succession of years with no change.

The Computer Program

This is a conceptual description of the program, for the listing, refer to Appendix V.

Data Setup

Data describing the district and the various relationships in the model are stored internally in the program in order to avoid an externally read data base. These sets of information are initialized in DATA statements (I.B.M., 1972; Organick, 1967) at the beginning of the program for easy reference by programmers.

The strata and blocks have been numbered sequentially from 1 to 20 and are referred to as SOURCE's[1/] in the program. Occasionally STRATA or BLOCK may be used for a more specific reference. For each of the twenty SOURCE's, the following location specific information is represented: VALUE (SOURCE)[2/] is a vector containing the value at risk for each SOURCE. EXPECT (SOURCE) is a vector containing the expected number of fires in each SOURCE. HAZARD (SOURCE) is the maximum amount of hazardous fuels that require modification in each strata each year. The blocks do not require fuel modification by burning because a similar effect is accomplished by fire break construction.

There are also a SHAPE (SOURCE) and a SCALE (SOURCE) that are the parameters of the gamma distribution used to describe the fire size characteristics for each source. By using a different set of parameters for each

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[1/] Here and in the following text, words with all capital letters will refer to variable names in the FORTRAN program in Appendix V.

[2/] The variable in parentheses is a subscript of the variable preceding it. Double subscripting will be done with a comma separating the two variables in parentheses.

cover type and source type, the realistically different characteristics for each one are simulated.

The effectiveness of each of the six prevention measures, specific to the strata in which it is applied, is represented in the matrix EFFECT (SOURCE, PLAN) where PLAN is the index of the individual fire prevention measure. The effectiveness for billboards, prevention contacts, and radio announcements is in terms of effectiveness per unit purchased. The effectiveness for controlled burning and mechanical crushing is in terms of the percentage of the maximum acreage of hazard that was treated. For fire breaks, the effectiveness is an all or nothing value depending on whether or not a break was assigned to the block.

Prevention Input Evaluation

The prevention strategy consisting of the assignment of various measures is evaluated and incorporated into a vector containing the resulting expected number of fires, FIRES (SOURCE). The original expected number of fires for the source, EXPECT(SOURCE), is reduced by a fraction, SUM, reflecting the sum of the effectiveness of the prevention efforts in each strata and block. The general equations are:

$$(1) \qquad SUM = \sum_{PLAN=1}^{3} [EFFECT(SOURCE,PLAN) \times UNITS(PLAN)] + \sum_{PLAN=4}^{5} [EFFECT(SOURCE,PLAN) \times MODIFY(PLAN,SOURCE)/HAZARD(SOURCE)] + EFFECT(5, SOURCE)$$

(2) FIRES(SOURCE) = EXPECT(SOURCE) x (1 - SUM)

Where: UNITS(PLAN) = The number of units of billboards, prevention contacts, and radio announcements are purchased.

MODIFY(PLAN, SOURCE) = The number of acres of fuel modified by burning (PLAN=4) and by crushing (PLAN=5).

EFFECT(5,SOURCE) only applies to the blocks and is a 0 or 1 variable depending on whether or not a fire break has been constructed.

There are also various coefficients and constants constraining the various sums to prevent the possibility of any prevention activity from becoming 100% or greater in fire prevention effectiveness.

The summing equation (1) assumes that the effectiveness of all prevention activities to be linearly additive. This may not be the case, but the method is convenient for programming the model and representing the relationship. The financial constraints generally prevent putting so many units of prevention in an area that the enterelationships become non-linear.

Fire Simulation

The randomness of the number of fires occurring each year in each strata and block is simulated using a normally distributed random number generator. The parameters of the distribution for each SOURCE are mean = FIRES (SOURCE) and standard deviation = 0.6 x FIRES (SOURCE). The normal random number generator is called once for each of the twenty SOURCE's to

determine the number of fires that will occur there during the simulated year.

The size of each fire is simulated by generating a gamma distributed random number.[1/] The distribution parameters SCALE and SHAPE specific to the SOURCE create a distribution tailored to the area. Using this method, a wide variety of fuel type and detection time situations may be simulated. The mean may be approximated by SHAPE x SCALE and the varience by SHAPE x $SCALE^2$.

Fires are located in a uniformly random pattern in strata and blocks using a uniform random number generator. Each fire is located randomly and independently. This may result in the same or overlapping areas being burned more than once in the same year. This could be interpreted as Spring and Fall burns or may be considered an unrealistic assumption made for programming convenience. Because of the relatively small percentage of the total area burned, less than 2%, fires on the same area seldom occur and are usually overlooked by the player. The feature was not included in the model because of the excessive cost and complication involved.

The fire size is generated as if no fire stations, other than the Bellyville Volunteers, were present. Then the program determines the traveling distance, GAP, from the nearest station. GAP is calculated as being the legs of the right triangle whose hypotenuse is a straight line between the station and the fire. Representing the traveling distance in this manner simulates the characteristic path along cardinal directions that country roads usually follow in the flatter sections of the Eastern United States.

[1/] The GAM algorithm is based on Johnk's Method, RAND Report R-641-PR, February, 1971, by M. B. Berman.

In any area, fire control personnel and equipment can seldom travel directly to a fire, so the cardinal direction convention serves as an approximation of the line of travel. The original fire size is then reduced by a function of GAP:

(3) SIZE = SIZE x (0.2 + 0.15 GAP)

Note that this algorithm accounts for only the closest fire station. No accounting is given for the possibility of having other stations assist on a fire or for the possibility of a single station having to fight more than one fire. There are no provisions for increasing the station capacity to handle such contingencies.

Fire Cost-Plus-Loss Calculation

The following rules were used to formulate the algorithm for determining cost and loss for a single fire:

Fire Size	Suppression	Damages
0.00-0.25 acres	Cost = $100	Loss = $000
0.25-10.0 acres	Cost = $500	Loss = $000
10.0-100. acres	Cost = $500	Loss = SIZE x VALUE/acre
100. plus acres	Cost = SIZE x $100	Loss = SIZE x VALUE/acre

The values for the individual fires are accumulated and displayed by strata and size class. The individual fire information is also stored and may be obtained by using the command DETAILS. For the total cost-plus-loss figure, all of the costs and losses for the individual fires are summed with the prevention and presuppression budget.

Adapting the Model

The program has been structured to accept alterations of the basic setup data without requiring changes in the programmed algorithm. There are several vectors and matrices that a programmer could change to fit data concerning a specific area or to reflect research data derived values. The values presently in the program were invented to represent an area that would serve the purpose of general instruction.

The effectiveness of any prevention method in any strata can be altered by changing the appropriate entry in the EFFECT (SOURCE, PLAN) matrix. The program will not accept information about the non-additivity of effectiveness without altering equation 1. The effectiveness of fuel modification can similarly be further manipulated by changing the HAZARD (SOURCE) vector. More strata or blocks may be added by increasing the columns in the above matrices and by adding the boundaries to the vector BOUND. Note that the appropriate dimensions and number of iterations in loops must be expanded to accommodate adding SOURCES.

The expected number of fires for the various SOURCES may be altered to reflect different characteristics. Note that if many are increased, the variables BURNED and DAMAGE must be dimensioned to accommodate the possibility of having more than 150 fires in a single year. The program subroutine GAUSS generates a normal distribution, but could be replaced by a POISSAN or other distribution by replacing the subroutine without changing the main program.

The fire size may be adapted to reflect local cover types or detection coverage by making appropriate changes in the SHAPE and SCALE vectors. The

GAMMA distribution is very flexible and may be adapted to approximate a wide variety of distribution shapes (see Appendix III for examples). There are no detection systems available to the player, but they could be added using the standing input routines and a fire size reduction formula similar to the fire station's. An alternative would be to directly alter the scale parameters of the GAMMA distribution by some function of the coverage intensity.

The fire model determines the number of fires as if they all happened at one point in time, in other words no consideration is given to sequence or how close they are together in time or space. A further modeling effort could produce a program that generates fires one by one in a stochastic sequence as in a queueing model (Wagner, 1970). This would enable the program to evaluate situations of multiple fires being fought at the same time by one or more fire stations. Time sequence modeling would also enable the consideration of seasonal changes in fire danger, spread index, and recreational use. Such a model change could be fit into the gaming input/output structure of the program with little difficulty.

Special Features of the Program

The game has three levels of comments on play programmed to be triggered by the total cost plus loss figure for the year. The comments are chosen randomly from tables of good, bad, and additional bad comments. The comments are intended to provide the player with incentive to improve play if poor and to reward him when his play is good. The comment selecting algorithm is flexible and more comments may be added with only a minimum

of program changes. The cutoff points for the various levels of comment may be changed by the instructor when running the game for various levels of expertise and experience.

The game also contains some hidden points which if burned, will cause political or social comment to be generated in the form of newspaper articles. These add to the interest of the game and make the player aware of sensitivity that may not be expressed in the dollars of value at risk.

The program contains an instructor's command mode that allows the instructor or person validating the program to make alterations and to change the output structure. These changes are made in plain language at the terminal and require no program changes or programming knowledge. The following may be of use to the instructor:

The command CUTOFF allows the instructor to reset the comment cutoff levels to better fit the expertise and experience levels of his players. Cutoff #1 is the upper limit of the good comments, #2 the lower limit of the bad comments, and #3 the lower lim. of the additional bad comments. Remember that even the best strategy, when applied in a bad year, may be judged poor in light of the cost-plus-loss criteria.

The command CLEAN may be used to remove all of the previous strategy with a single command. This allows the instructor to set the budget to zero without unloading the object program. This should be useful when more than one player is to play in a single session.

The following commands are useful in validation of the program or examining the effects of data changes:

The command EXPECT causes the matrix FIRES (SOURCE) to be printed out for each yearly cycle. This is a display of the results of the fire

prevention strategy's effect on the expected number of fires in each strata and block. The actual occurrence is a random number and a poor means of evaluating strategy on a one year basis. These expected values are the average number of fires that should occur in the area if the same strategy were run for a "long time."[1/]

The command SIZE causes the unreduced (by effect of fire station) fire size to be printed out each year. This provides a measure of the fire station effectiveness function. NOBUDGET suppresses the budget summary to shorten printing time during debugging or validation runs.

Simulation Response and Validation

The model simulates the response of the system to the prevention and presuppression measures employed by the planner. The response may be thought of as the change in state of the system due to the measures employed. The responses of the system's fire size were evaluated using a 2000 iteration Monte Carlo procedure.[2/] The FLASHFIRE program was modified to print out the expected values for the numbers of fires in the strata and blocks. This output was used to obtain the figures in Table 1, an evaluation of system response to prevention measures. These two procedures are used to illustrate the average response or expected response without the masking because of randomness in a single run.

The initial state of the system will first be described to provide a point of reference for the changes that occur. Fire size is distributed according to the Gamma function of the SIZE and SHAPE parameters of each

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[1/] See appendix III for Monte Carlo examples of "long time."

[2/] See Appendix IV for the programs used for the procedure.

strata and block. Bellyville,[1/] for example, is characterized by relatively small amounts of available fuel and a short fire detection time. The fire size distribution in this situation (Figure 3) indicates a probability that all fires will be small (house fires have not been included in this simulation). A more heavily wooded area with large quantities of available fuel and few people to spot fire starts has a different shape to its fire size distribution (Figure 3). The example used, Strata 8, has a curve skewed more to the right indicating a larger average fire size and greater probability of large fire occurrence. Appendix III has more examples of Gamma distributed fire size probability density functions.

The initial expected numbers of fires in each stratum and block follow an important pattern (Example 1, Table 1). The expected numbers pattern in the strata indicate that more fires are expected in Strata 2, 6, 7, 8, and 9 than in the others. This state is because of larger amounts of available fuel (2,6,7,8), higher density of fire building campers (2,9), and logging operation accidents (2,6,7). Expected numbers of fire starts along the highway, Blocks 17, 18 and 19, are equal indicating an equal probability of a discarded piece of burning tobacco, equipment spark, or other accidental or intentional fire causing occurrence. Along the railroad, Blocks 11 to 15, the larger expected numbers occur on the grades, Blocks 12 and 13, than on the flatter areas. This occurs because diesel engines build up carbon while lugging up-grade and blow out burning carbon while running free down-grade (Crosby, 1972). More fire starts are

[1/] See Map in Appendix I.

EXAMPLE PROBABILITY DISTRIBUTIONS

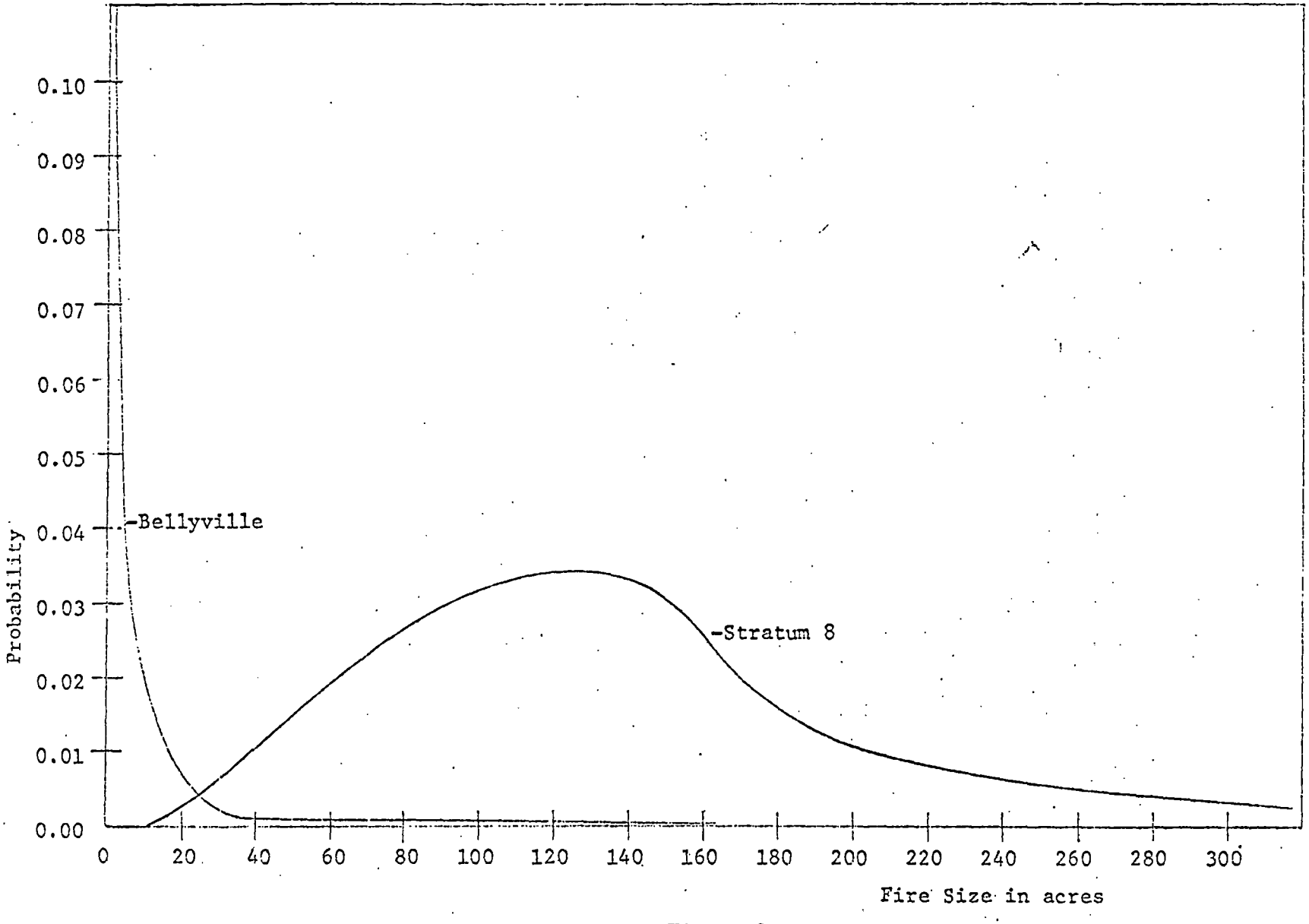

Figure 3.

expected around the dump and camp, Blocks 20 and 16 respectively, which represent typical situations.

These size and expected number of fire patterns describe the initial state of the system. Prevention and presuppression measures modify the initial states by stratum and block. The following are examples of the effects of increasing levels of prevention and protection measures (example numbers refer to Table 1):

Billboards, Example 2. The addition of the first ten billboards reduced the expected number of fires along the road by two per Block, Blocks 17, 18, and 19. Sharply decreasing returns are noted when an additional ten billboards are added resulting in the reduction of only one expected fire per block. The effect on the other strata and blocks was minimal, but when 100 billboards were used, there was noticeable response. The effect on campers driving to the woods (Strata 2 and 9) and loggers driving to work (Strata 7 and 8) is reflected in a reduction of one expected fire per strata.

Prevention Contacts and Radio Announcements, Examples 3 and 4. Effects of these measures are apparent in areas frequented by the people that they have reached. For example, summer recreationists in Stratum 2 and Block 9 are reached by both prevention contacts and radio announcements. The two measures require large expenditures to achieve the saturation required to obtain noticeable results. For example, the cost of 100 radio announcements is $100,000 and the effect is the prevention of only an average of five fires per year.

EXPECTED NUMBERS OF FIRES

Decision	Strata Number 1	2	3	4	5	6	7	8	9	10	Block Number 11	12	13	14	15	16	17-19	20	Total
Example #1																			
no strategy	4	6	4	2	2	6	20	10	6	4	2	10	10	2	2	6	4	10	118
Example #2																			
10 billboards	4	6	4	2	2	6	20	10	6	4	2	10	10	2	2	6	2	10	112
20 billboards	4	6	4	2	2	6	20	10	6	4	2	10	10	2	2	6	1	10	109
100 billboards	4	5	4	2	2	5	18	9	5	4	2	10	10	2	2	5	0	10	99
Example #3																			
10 contacts	4	6	4	2	2	6	20	10	6	4	2	10	10	2	2	6	4	10	118
20 contacts	4	6	4	2	2	6	20	10	6	4	2	10	10	2	2	6	4	10	118
100 contacts	4	5	4	2	2	6	18	9	5	4	2	10	10	2	2	5	4	9	112
Example #4																			
10 radio ann.	4	6	4	2	2	6	20	10	5	4	2	10	10	2	2	6	4	9	116
20 radio ann.	3	6	3	2	2	6	20	10	5	4	2	10	10	2	2	6	4	8	113
100 radio ann.	0	5	0	2	0	5	18	9	0	4	2	10	10	2	2	5	2	0	80
Example #5																			
all breaks	4	6	4	2	2	6	20	10	6	4	1	2	3	1	1	1	1	2	78
Example #8																			
30 billboards	4	6	4	2	2	6	19	10	6	4	2	10	10	2	2	6	0	10	105
30 contacts	4	6	4	2	2	6	19	9	6	4	2	10	10	2	2	6	0	10	104
30 radio ann.	3	5	3	2	1	6	18	9	6	4	2	10	10	2	2	6	0	7	92
add breaks																			
12,13,16 & 20	3	5	3	2	1	6	18	9	4	4	2	1	2	2	2	1	0	0	65
burn (acres)		(400)				(400)	(600)	(400)											
expected fires	3	2	3	2	1	1	5	0	4	4	2	1	2	2	2	1	0	0	35

Table 1.

(Continued on page 40)

EXPECTED NUMBERS OF FIRES

Decision	Strata Number 1	2	3	4	5	6	7	8	9	10	Total 1/
Example #6											
burn (acres)	(200)	(200)	(200)	(200)	(200)	(200)	(200)	(200)	(200)	(200)	
expected fires	4	4	4	2	2	4	15	4	6	4	103
(acres)	(400)	(400)	(400)	(400)	(400)	(400)	(400)	(400)	(400)	(400)	
expected fires	4	3	4	2	2	2	11	0	6	4	92
(acres)		(600)				(600)	(600)	(600)	(600)	(600)	
expected fires	4	1	4	2	2	0	7	0	6	4	84
(acres)		(800)				(600)	(800)	(600)	(800)	(800)	
expected fires	4	0	4	2	2	0	2	0	6	4	78
Example #7											
crush (acres)		(400)				(400)	(400)	(400)			
expected fires	4	6	4	2	2	1	10	0	6	4	93
(acres)		(600)				(600)	(600)	(400)			
expected fires	4	6	4	2	2	0	7	0	6	4	87
(acres)		(800)				(600)	(800)	(400)			
expected fires	4	6	4	2	2	0	0	0	6	4	82

Table 1. (continued)

1/ The totals in this column include the unlisted 54 fires expected in the Blocks.. These figures were not changed by the burning or crushing.

Fire Breaks, Example 5. Establishment of a fire break reduces the expected number of fires in the Block by from 70 to 80%. This may seem high, but the change in state is pronounced and clear to the player. This contrasts the clearly defined effect of on the ground effort with difficult to visualize effects of radio announcements and prevention contacts.

Controlled Burning, Example 6. Controlled burning of strata has a similar effect to building fire breaks in the blocks. Because of this, the game does not allow building fire breaks around strata or controlled burning in blocks. Burning 200 acres in each stratum reduced the expected numbers of fires in Strata 2, 6, 7, and 8. Strata 2, 7, and 8 were affected because of the logging slash left each year. Stratum 6 was affected because of light combustible fuels present in the dry brushy area. It is further shown that increasing acreage burned will further reduce expected numbers of fires in these strata but will not affect the strata where burning is not practical. For example, fires in the farmland occur in crop or pasture land and burning these fuels to prevent fires would be out of the question.

Mechanical Crushing, Example 7. Mechanical crushing effects followed similar patterns to Controlled Burning. Effects were somewhat less because the measure still leaves large amounts of available fuels, even though they are less combustible.

The additive effect of a series of prevention measures is shown in example 8.[1/] This effect is modeled linearly, the last line represents the

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[1/] Appendix II contains an example run of this strategy.

effect of the linear sum on the initial expected values. Note that if a planner had this explicit information, he could indeed direct his resources to their optimum use.

Fire Stations, Figure 4. Effect of fire stations on fire size probabilities is best visualized in terms of probability density functions. Having a station in the neighborhood, for example with range (R) = 0 miles, will result in a curve as pictured with a mean of 20 acres, variance of 78, and a maximum size of 56.8 acres in 2000 simulated fires. As the range to the fire increases, the curve becomes skewed right and flattened out. This change of shape indicates a larger average fire size and greater variability. The curve for R = infinity would be nearly flat on this scale, but statistics are included for comparison purposes. The infinite range would be the situation for new fire stations, remember from the scenario that there is a volunteer fire department in Bellyville.

Now that the responses have been described, the question often arises "Are these responses valid?" (Boocock, 1971). There are three types of bases for the answer:

1. Theoretical validity, extent to which results conform to theoretical or logical principles.
2. Empirical validity, closeness of fit of simulation results to other measures that serve as "criteria" of the phenomenon under study.
3. Face validity, extent to which results "seem" to be reasonable.

EFFECT OF FIRE STATION PROXIMITY ON FIRE SIZE DISTRIBUTION IN STRATUM #8

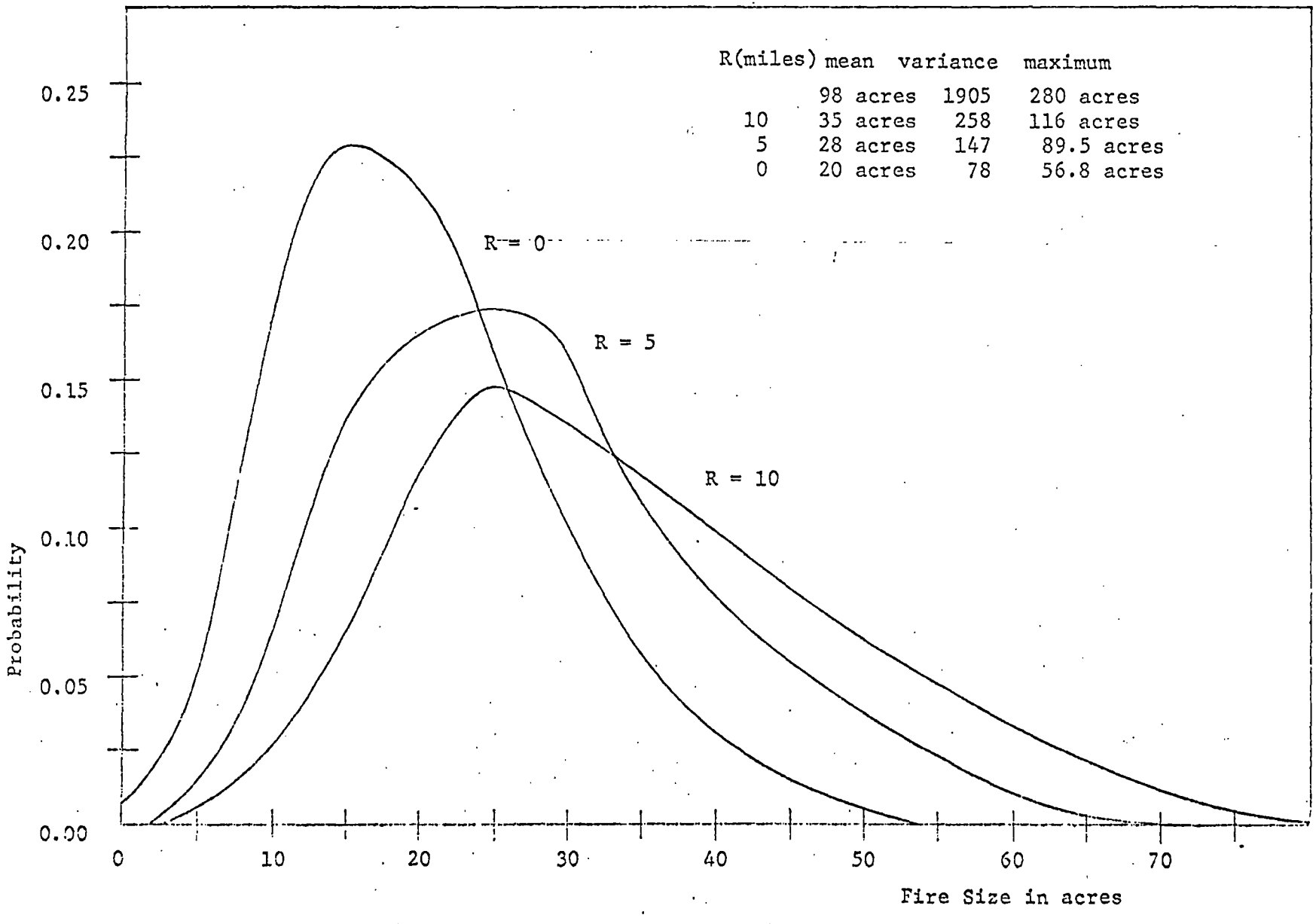

Figure 4.

These need to be considered carefully in terms of the uses of the model. Validation by some criteria may not be as critical as when the model is to be used for analytic purposes such as prediction or hypothesis testing (Countryman, 1973).

The responses that have been discussed have theoretical validity in terms of qualitative logic. Experience and the references support this claim, but quantitative effects are not included in this support. In this, the model identifies needs for empirical information about real world situations. Since the data and situation are hypothetical, empirical validation by comparison to the "real world" cannot be done. First, the input information would require on-the-ground study to empirically derive the effect coefficients and states of probability. This process was not necessary for the construction of the game as a training device because the simulation required only face validity. The results did seem reasonable to a majority of the students and professionals who played the game during its development.

This section has described the inputs and outputs of the computer model as if it were a black box. The changes in state are hypothetical, but they provide a basis for real world studies to center upon. The black box as it has been constructed can be changed to produce different responses. Thus, if one disagrees, the model can be altered to better approximate new ideas or empirical data.

Discussion of the Planning Lesson

A person who sits down to play the game for the first time, regardless of fire control and prevention planning experience, faces a common planning problem. He cannot be certain of exactly how the system will respond to his

manipulations or what the present state of the system is. Information can be obtained, as well as fires prevented or controlled, within the strategy. This is the basic planning exercise that the game provides for the player.

The player's stated objective is to minimize the cost-plus-loss of the forest fire prevention and control effort. He is to accomplish this by implementing a strategy comprised of various resource (money in this case) allocations to means of achieving the objective (Miller, 1967). These processes are clearly defined, e.g., buy billboards to prevent fires along the highway. But what of the problem posed in the previous paragraph? Can these decisions be made effectively, considering the players ignorance of the system and its responses? There are short run problems to be solved on the way to achieving the stated objective.

One can easily visualize on-the-ground tactics employed in the strategy of prevention and presuppression effort. But prior to being able to effectively use these tactics, the planner must achieve a short run goal of improving his knowledge of the system state and response. These have been discussed in detail in this text, but hopefully the player will not have "read the book before seeing the movie." Thus, the first tactic employed is to obtain information about the system. The short term goal could be visualized as movement along a line from perfect ignorance towards certainty, but not reaching it (Bentley, 1973; Shackle, 1970).

The starting information for the player may be dependent upon the instructor, but consider the situation where only the computer supplied "value at risk survey" and "fire history" are available. The player must

guess at a strategy based on his experience and limited information. After running the simulation of a year and evaluating the output as feedback, he changes his tactics according to his improved knowledge of the system and its responses. This places him in the position of the regulator in a cybernetic system (Miller, 1967; Simon, 1969). The player improves his information by evaluating year by year feedback and correcting his strategy by altering tactics. The measure of his effectiveness is the response of the system in terms of his objective of minimizing cost-plus-loss.

Stepping through this process provides the player with a heuristic experience. He faces the problem of incomplete information (uncertainty) and attempts to solve it by utilizing system feedback. The feedback contains the lessons in fire prevention and presuppression tactics. Thus the dual purpose of the game is served by providing experience in planning under uncertainty and experience in some practical fire control principles.

APPENDIX I

A GUIDE TO FLASH FIRE

This guide was written by the author and Alfred Maley for inclusion in the Natural Resource Management Game Package, School of Natural Resources, University of Michigan, Ann Arbor, based on notes and instructions developed by this author. There are some differences between the Guide description and the description contained in this report. These discrepancies are intended to make the game conform to the Package and do not represent errors in the Manual. The major difference is that the report contains a more complete scenario than is contained in the Guide.

Because of the length and importance of the computer program listing, the Programmer's Guide is found in Appendix V instead of following the Instructor's Guide. The texts of all of the sections of the Guide are computer produced so that the page numbers in the upper right hand corners are Guide section page numbers.

FLASH FIRE

A FIRE CONTROL GAME

A GUIDE TO FLASH FIRE

PREFACE

This document is divided into several distinct sections, each of which is designed for a specific person. The titles of the sections are

OVERVIEW AND RATIONALE

USER'S GUIDE

INSTRUCTOR'S GUIDE

PROGRAMMER'S GUIDE

OVERVIEW AND RATIONALE

OBJECTIVES OF THE PROGRAM

FLASH FIRE presents the player with various possible sources of fire danger and require him to formulate strategies to minimize the cost plus loss due to fire control, utilizing the various options available to a typical fire manager in the northeastern United States.

Specifically, the program presents the player with a 2500 square mile area consisting of ten subareas with varying land values and fire origins (railroads, highways, etc.) with consequent variations in probabilities of fire occurrence and size. The alternatives the player has at his disposal, given a fixed budget, include the number and location of fire stations, location and extent of fuel modification and fire breaks, radio announcements, billboards and fire prevention contacts.

As a secondary objective, the game serves as an introduction to the techniques of computer simulation of management problems.

LEVEL AND BACKGROUND OF THE USER

The typical user would be an undergraduate studying forest fire prevention and control or general resource management.

LIMITATIONS

The game is a simplification of reality, of course, and does not purport to present the full range of possible situations nor the complexities involved in the options of fire prevention and control.

HISTORY OF THE PROGRAM

FLASH FIRE was initially developed with the support of National Science Foundation Grant GJ-333 and the cooperation of the Forest Service. The Forest Service later supported revisions and extensions.

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OVERVIEW AND RATIONALE

USER'S GUIDE

GENERAL INFORMATION

The player has just been assigned as fire manager for the 2500 square mile Beaver Belly Forest District. This district is generally forested, but there is also considerable agriculture. In addition there are a few pockets of high value residential area. Route 2, a highway of no little historical value, bisects the district. A spur of the Beaver Belly & Buffalo Chip Railroad also traverses the area, providing Bellyville a link with the outside world.

The objective is to minimize the total of the cost of fire prevention and control and the loss due to fire damage. The management options available to attempt to do this include:

- number and location of fire stations
- location and extent of fuel modification and fire breaks
- radio announcements
- billboards
- fire prevention contacts
- purchase of fire history information
- purchase of value at risk information

The manager has a budget of $500,000 to use for the above options. The costs of the above options are listed in the following table:

Item	Cost	Remarks
Fire stations	$50,000/yr.	Must be retained for five years
Fire break	$5,000/yr.	Breaks are located as indicated on the map; length is 10-15 miles, width is 2 chains along RR, roads, 1 chain around camp, dump
Controlled burn	$100/acre	Optimally located in the strata
Mechanical crush	$150/acre	Same as burning but safer
Radio announcements	$5,000/yr.	Series of five
Prevention contacts	$1,000/yr.	Series of five
Billboards & visual devices	$500 each	
Fire history	$500	
Value at risk/acre survey	$10,000	By strata
Projection	$10,000	

WAYS TO USE THE PROGRAM

Initially the player may wish to explore the relationships between prevention techniques and the number of fires, disregarding the cost. Later this knowledge may be used to formulate good strategies to minimize the cost plus loss figure.

OUTPUT DATA GENERATED

The program outputs the following data for each year of play:
- a tabular summary of the number and damage of fires by size class
- a tabular summary of the fires by subarea (optional)
- details on any or all of the fires in a subarea

Also, the player may request (at a cost)
- a verbal fire history of the district
- a value at risk summary, payable over a five year period
- details on any or all of the fires in a subarea
- a projection of the long term effect (10 years) of a given policy

BASIC OPERATION

Sign on the terminal as per the instruction sheet provided by the instructor. The player should be sure that the instructions correspond to the type of terminal he is using.

STARTING THE PROGRAM

The player should enter the command

RUN **** FLASHFIRE

unless indicated otherwise by the instructor.

SPECIAL COMMANDS

The player directs the sequence of events in the game. He starts by entering the following commands that allow him to input the management strategy:

fire STations

fire BReaks

BUrn

CRush

verbal HIstory

VAlue at risk

RAdio announcements n

COntacts n

BIllboards n

Only the capitalized letters need be entered. n is the number of that item (billboards, radio announcements, etc.) that the player wishes to have. The other commands require more information and the user will be queried as to the details. The program prompts for more information about a given command with a colon. Additional information usually consists of ADDing or DELeting an item. For example, the following would add a fire station at (3,40):

```
? fire station
: add at 3,40
:
?
```

Here the end of entry of fire stations is terminated by a blank line.

After entering his strategy the player may start the simulated year by entering the command

GO

If the budget items contained in the startegy do not exceed $500,000 the simulation begins. If the budget is exceeded the player is so informed and he must alter his strategy to fit within the budget.

After the year is simulated the player may buy a projection of the effects of his strategy over the next ten years. The cost is subtracted from his next year's budget. The command to obtain this projection is

PRojection

Note that the program will extract information from the lines of text entered by the player. A check on the validity of the input is provided by the summary of the strategy given after the command GO.

ERROR PROCEDURES

The player may backspace or delete to correct errors that have not been sent to the computer. Illegal commands and input will be intercepted by the game and the player asked to reenter the correct information.

INTERRUPTING THE PROGRAM

The program may be interrupted by pressing the interrupt or attention button. Some teletypes require that the player press a button that lights up after an interrupt before continuing.

RESTARTING THE PROGRAM

USER'S GUIDE

The program may be restarted as in STARTING THE PROGRAM. The only way to reproduce the sequence of events leading up to the interrupt is to reenter all the strategies.

OBTAINING THE OUTPUT DATA

The above mentioned regulalrly scheduled output is automatic. Optional items are outputted immediately after the player requests them.

ENDING THE PROGRAM

To end the game the player should enter the command

```
Finish
```

ANNOTATED TRACE

The following is a sample run with appropriate comments:

```
run flashfire
EXECUTION BEGINS

                *** F L A S H   F I R E   II ***
                      FEB  1, 1973

 DO YOU WANT A DESCRIPTION, YES OR NO? no
 PRICE LIST, YES OR NO? no
ENTER STRATEGY
? billboards 12
BUDGET =$   6000.
? bil 5
BUDGET =$   2500.
? contacts 3
BUDGET =$   5500.
? contacts 0
BUDGET =$   2500.
? radio 3
BUDGET =$  17500.
? radio 6
BUDGET =$  32500.
? burn 1 200
BUDGET =$  52500.
? burn 1 0
BUDGET =$  32500.
? crush 2 100
BUDGET =$  47500.
? crush 2 400
BUDGET =$  92500.
? stations
: add 25 25 34 60
:
BUDGET =$ 192500.
? sta
: del 34 60
:
BUDGET =$ 142500.
? breaks
: add 16 20
:
BUDGET =$ 152500.
? bre
: del 16
:
BUDGET =$ 147500.
? burn 7 100 8 150 9 100
BUDGET =$ 182500.
?
```

} to obtain these, type YES

Sets number of billboards at 12

Accumulates Budget Allocations

Sets number of billboards at 5 to alter strategy

Note that keywords may be abbreviated to 3 letters

Note: Contacts & Radio announcements are selected and altered in the same manner as billboards. May increase, decrease, or set to zero. All are initially set to zero.

Elects to do controlled burning on 200 acres in Strata #1.

Sets controlled burning acreage in Strata #1 to Zero.

Mechanical Crushing may be elected and altered in the same manner as burning.

Push return after entering the keyword "stations"

This places stations at coordinates X = 25, Y = 25 and X = 34 and Y = 60 (Two fire stations)

Push return to get out of this mode.

This deletes the previously established station at 34, 60.

Note that in deleting and electing fewer numbers that the budget is reduced accordingly.

To add or delete firebreak blocks, only the numbers 11 through 20 are legal. Up to 10 may be added or deleted in a string.

burning and crushing selections may be made in strings of up to 5. Here 100 acres in S. #7, 150a. in S #8, and 100 acres in S. #9 are selected.

go Begins the simulation

STRATEGY SUMMARY

BILLBOARDS	CONTACTS	RADIO A.	BURNING	CRUSHING
2500.	0.	30000.	35000.	60000.

FIREBREAKS	F.STATIONS	F.HISTORY	VAL AT RISK	PROJECTION
5000.	50000.	0.	0.	-0.

All table units in dollars.

YEARLY $ SUMMARY

TOTAL FIRES PER STRATA IN PARENTHESES

STRATA	CLASS A	B	C	D	E
2(11)	0.	500.	467594.		
4(1)	0.	500.			
6(12)	0.	0.	168147.	231501.	47163.
7(10)	100.	0.	634252.		
8(3)	0.	0.	216312.		
9(10)	0.	500.	749595.		
10(2)	100.	500.			

Sum of cost+ loss results for all class E fires in strata # 6. Note there were 12 fires altogether in strata # 6 this year.

TOT FIRES= 49 ,AV. FIRE SIZE= 66.43
TOTAL ACREAGE = 3255. TOTAL COST+LOSS= 2699255.

This figure includes your presuppression budget. Your objective is to minimize this number. Comments are generated accordingly.

UPI WIRESERVICE FLASH
DATELINE BELLYVILLE
THE ENVIRONMENTAL PROTECTION AGENCY ANNOUNCED THAT DUE TO THE 49 FIRES ON THE BEAVER BELLY DISTRICT THIS YEAR THAT THEY HAD TO DESIGN A NEW SCALE FOR THEIR MURC INDEX. THEY HAVE INITIATED AN INVESTIGATION INTO THE FIRE PREVENTION AND CONTROL METHODS EMPLOYED SO THAT APPROPRIATE LEGISLATION MAY BE ENACTED TO PREVENT IT FROM EVER HAPPENING AGAIN

Use this procedure to obtain details about fires in a particular strata. Strata 6 in this case, specifying d returns all fires of size class d and larger. There is no charge for this information.

```
details 6
MINIMUM CLASS FOR STRATA  6: d


STRATA  6
 X    Y     AREA     COST+LOSS
 80,  24   149.98      22747.
 70,  42   131.93      20491.
 83,  22   110.38      17798.
 62,  44   163.66      28457.
 82,  45   132.72      20590.
 81,  22   255.87      39984.
 78,  36   313.31      47163.
 72,  32   172.84      29605.
 84,  49   101.28      16660.
 72,  48   217.35      35168.
? details 10
MINIMUM CLASS FOR STRATA 10: a


STRATA 10
 X    Y     AREA     COST+LOSS
 60,  83     1.90        500.
 49,  94     0.07        100.
? projection
```

This keyword obtains a projected evaluation of your strategy. Cost is $10,000.

```
EXPECTED YEARLY AVERAGES FROM 10 YEAR PROJECTION
COST+LOSS= $  3136767.   ACREAGE=   3162.
```

This command runs the simulation for 10 "average" years and then averages the results.

```
BUDGET =$ 192500.
? finish
```

← Finish Terminates Play.

```
THANK YOU FOR PLAYING FLASH FIRE II

#EXECUTION TERMINATED
#
```

SUMMARY OF COMMANDS

GO

Billboards n

BUrn

COntacts n

CRush

FInish

fire BReaks

fire STations

PRojection

RAdio announcements n

VAlue at risk

verbal HIstory

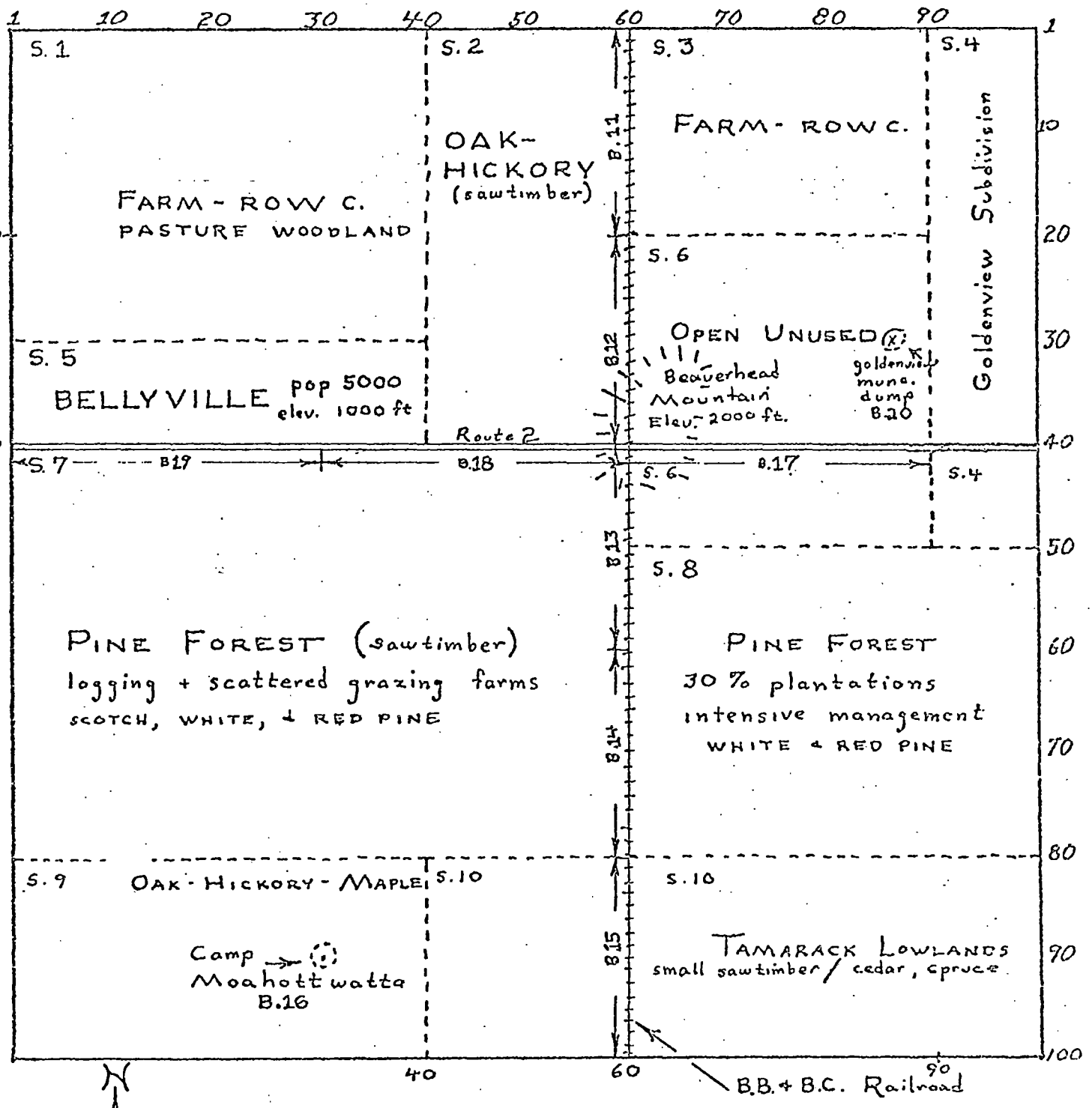
Also

ADD at string

DELete at string

where "string" means the two coordinates of a fire station or one or more block numbers. These numbers must be separated by blanks or commas.

BEAVER BELLY DISTRICT



SCALE 2 GRID UNITS = 1 MILE

B. # BLOCK NUMBER

S. # STRATA NUMBER

- - - - - TYPE (STRATA) BOUNDARY

═══ PAVED HIGHWAY

+++++ RAILROAD

SUMMIT

INSTRUCTOR'S GUIDE

CURRENT STATUS

FLASH FIRE, now in its second version, has been used in the classroom since January, 1973.

WHERE OPERATING

The game has been operating on the Michigan Terminal System (MTS) at the University of Michigan, Ann Arbor.

DATE LAST REVISED

May 1, 1973

STRATEGIES FOR USING THE PROGRAM

FLASH FIRE is designed as an activity for a single laboratory period, where copies of the USER'S GUIDE have been distributed to the players prior to the session. A "no strategy" run of the game may also be distributed beforehand as background material. The instructor may describe the "no strategy" run as an inefficient fire control program that the player is to improve upon.

The instructor may vary the levels of cost plus loss that result in favorable or unfavorable comments. This allows him to run the game according to the proficiency of the student, making it interesting to the beginner and expert alike. See the section on POSSIBLE MODIFICATIONS.

SIZE OF USER GROUP

Three or four students seems to be the optimal size group due to the need to see the terminal output and to develop strategies efficiently.

LEVEL OF USER

The user should have some background in fire control planning, but this is not necessary.

MODEL EMPLOYED IN THE PROGRAM

The model is very simple. Each strata has a basic "expected" number of fires that would occur without any control. That number is reduced by a coefficient that purports to sum the effects of all the control methods. Thus

fires with control = # fires without control X reduction coefficient

The reduction coefficient, a hypothetical concept, is determined as

$$1 - \sum_{i=1}^{\#\ options} \text{units of option } i * \text{effect of option } i \text{ in this strata}$$

This sum is designed and limited in such a way that it has a value between 0 and 1. A reduction coefficient of 1 implies no control; a coefficient of 0 implies complete suppression.

TIME REQUIREMENTS

Users require about a half hour to plan their first year's strategy after a 15 minute introduction by the instructor. About one hour is required to make five or six runs while perfecting a strategy, at a cost (under MTS) of about $5 an hour.

SOURCES OF ASSISTANCE

Dr. William Bentley
School of Natural Resources
University of Michigan
Ann Arbor, Mi. 48104

POSSIBLE MODIFICATIONS

The instructor may adapt the game to local conditions by changing, in the source program, those coefficients that relate to prices, the expected number of fires, the amount of hazardous fuels in an area and the effectiveness of the various fire control methods. In addition he may vary the distribution of fire sizes by changing the parameters of the gamma function size generator. The variables that control these elements in the program have the names PRICE, EXPECT, HAZARD, EFFECT, SHAPE and SCALE. To modify them the instructor should consult the PROGRAMMER'S GUIDE.

As an aid to the instructor in validating any changes he might make in the above variables, the program allows the instructor to inspect the workings of the program by entering the special command INstructor, where only the first two letters need be entered. The program will respond with a colon after which any of the following commands may be entered.

COMMAND	RESULT
SIze	prints the average fire size each year; used to observe the effectiveness of fire stations.

INSTRUCTOR'S GUIDE

CLean	deletes all stored control items
EXpected	prints the matrix of expected fires by strata under a given strategy
NOEXpected	suppresses the above
NOBudget	suppresses the strategy budget summary
BUdget	restores the printing of the budget summary
CUtoff n,nnnn	sets cutoff point n (for comments) at a cost plus loss value of nnnn.

APPENDIX II

EXAMPLE RUN OF FLASHFIRE

The first year is run with no strategy to provide an example of the initial state. The second year uses the strategy developed in Example 8 of Table 1. Some examples of details of individual fires are also provided.

```
run flashfire
#EXECUTION BEGINS

                    *** F L A S H   F I R E   II ***

 DO YOU WANT A DESCRIPTION, YES OR NO? no
 PRICE LIST, YES OR NO? yes

  P R I C E   L I S T

BILLBOARDS $  500.EA/YR   CONTACTS $ 1000./5/YR
RADIO ANN. $ 5000./5/YR   BURNING  $  100./A/YR
CRUSHING   $  150./A/YR   BREAK    $ 5000.EA/YR
STATION    $ 50000./A/YR, FOR FIVE YEARS
HISTORY OF FIRE $  500.   VALUE AT RISK $10000.
PROJECTION $10000.



ENTER STRATEGY
? go

STRATEGY SUMMARY
BILLBOARDS   CONTACTS   RADIO A.   BURNING   CRUSHING
        0.          0.         0.         0.         0.
FIREBREAKS  F.STATIONS F.HISTORY  VAL AT RISK PROJECTION
        0.          0.         0.         0.         0.


    YEARLY COST+LOSS SUMMARY

TOTAL FIRES PER STRATA IN PARENTHESES
          CLASS
STRATA    A       B       C        D         F
  1( 1)   0.      0.     3688.
  2( 8)   0.      0.     9987.   207312.
  3( 3)   0.   1500.
  4( 3) 100.   1000.
  5( 1)   0.    500.
  6( 9)   0.      0.   501003.    60063.
  7(36)   0.   1500.   131998.   409127.   237591.
  9(16)   0.    500.   243450.
 10( 5)   0.    500.     6947.

TOTALS: FIRES= 82, ACREAGE=  5414.
COST+LOSS=$  1816753., AV. FIRE SIZE 66.02 ACRES
```

```
 details 2 6
MINIMUM CLASS FOR STRATA  2: a


STRATA  2
 X    Y     AREA     COST+LOSS
 51,  13   155.27     23291.
 44,   1    83.54      4677.
 42,  16    70.94      4047.
 48,  20   171.61     41742.
 51,   1   156.26     23439.
 54,   7   135.23     20285.
 60,  18   177.04     98556.
 60,  25    15.26      1263.
MINIMUM CLASS FOR STRATA  6: a


STRATA  6
 X    Y     AREA     COST+LOSS
 72,  43   172.18     29522.
 66,  41    33.68     51021.
 84,  41    46.65     70475.
 66,  41    18.29     27931.
 81,  41    59.35     89523.
 75,  41    89.05    134072.
 66,  41    52.92     79876.
 78,  41    31.74     48107.
 85,  29   180.32     30540.
? details 7
MINIMUM CLASS FOR STRATA  7: d

LINE DELETED:  DATA CHECK
 d


STRATA  7
 X    Y     AREA     COST+LOSS
 32,  67   107.75     21550.
 54,  55   161.10     64221.
 16,  75   357.98    119595.
 51,  64   107.79     21559.
 59,  54   246.76     81353.
  7,  67   136.79     27358.
 36,  57   165.83     65167.
 29,  63   169.80     65959.
  1,  60   349.98    117996.
 60,  48   167.84     61961.
?
```

```
? billboards 30
BUDGET =$  15000.
? contacts 30
BUDGET =$  45000.
? radio 30
BUDGET =$ 195000.
? burn 2 400 6 400 7 800 8 400
BUDGET =$ 395000.
? breaks
: add 12 13 16 20
:
BUDGET =$ 415000.
? go

STRATEGY SUMMARY
BILLBOARDS   CONTACTS   RADIO A.   BURNING   CRUISING
    15000.      30000.    150000.    200000.         0.
FIREBREAKS  F.STATIONS F.HISTORY  VAL AT RISK PROJECTION
    20000.          0.         0.         0.         0.


    YEARLY COST+LOSS SUMMARY

          CLASS
STRATA    A      B      C        D        F
  1( 3)   0.   500.   13929.
  2( 8)   0.   500.   20726.    62471.
  3( 2)   0.   500.    5531.
  4( 1) 100.
  6( 3)   0.     0.       0.    52541.
  7( 4)   0.     0.    8256.   180791.
  9( 3)   0.   500.   26125.
 10( 2)   0.     0.    3340.

TOTALS: FIRES= 26, ACREAGE=  1828.
COST+LOSS=$   790810., AV. FIRE SIZE 70.32 ACRES



ENTER STRATEGY
? details 2
MINIMUM CLASS FOR STRATA  2: c


STRATA  2
 X   Y    AREA    COST+LOSS
 52, 33  140.26    21040.
 55, 30  169.54    41432.
 50, 39   93.13     5156.
 60, 10   80.94     4547.
 60,  7   38.30     2415.
 60, 28   64.18     3709.
 60, 22   87.99     4900.
?
```

```
? details 6 7
MINIMUM CLASS FOR STRATA  6: a


STRATA  6
 X    Y     AREA     COST+LOSS
 86,  47   150.64      18830.
 79,  40   119.05      14881.
 61,  25   150.64      18831.
MINIMUM CLASS FOR STRATA  7: a


STRATA  7
 X    Y     AREA     COST+LOSS
 60,  47    51.70       8256.
 60,  55   103.83      25959.
 60,  63   108.71      27178.
 60,  63   254.62     127654.
?

? projection

EXPECTED YEARLY AVERAGES FROM 10 YEAR PROJECTION
COST+LOSS= $    625600.    ACREAGE=    1239.




BUDGET =$ 425000.
? finish

 YEARLY AVERAGES FOR YOUR PLAY
NUMBER = 33. FIRES
SIZE= 3458. ACRES
COST+LOSS =$1045987.

THANK YOU FOR PLAYING FLASH FIRE II


#EXECUTION TERMINATED
#
```

APPENDIX III

MONTE CARLO DESCRIPTIONS OF FIRE SIZE PROBABILITY DISTRIBUTION FUNCTIONS

The following distribution functions were obtained from 2000 iteration Monte Carlo runs of the Gamma generating function GAM. The 2000 random variates were then grouped into five acre classes using the Michigan Interactive Data Analysis System (MIDAS) available on the Michigan Terminal System, University of Michigan, Ann Arbor. The probabilities for the intervals were then calculated and the approximate functions plotted. The programs used to generate the random variates are contained in Appendix IV.

Table III-1. contains the Monte Carlo approximations of the mean and variance of the gamma functions for the various strata and blocks. The three figures, III-1, III-2, and III-3, contain plots of some of the probability distributions used. Some of the SOURCE's are not included because of close similarity with those that are included. The figures are labeled by SOURCE number, for example S2 is Stratum 2 and S14 is Block 14.

SUMMARY OF MONTE CARLO TESTS

SOURCE	TYPE	Shape	Scale	Expected Mean	Expected Var.	Monte Carlo Mean	Monte Carlo Var.	Max.
1	Farm	2.0	10.0	20	200	20.3	200.8	84
2	Hardwood	6.0	20.0	120	2400	119.2	2340.1	300
3	Farm	0.5	20.0	10	200	9.4	184.4	120
4	Subdiv.	.055	40.0	2.2	88	2.1	78.5	104
5	Town	.055	40.0	2.2	88	2.1	78.5	104
6	Open	4.0	40.0	160	6400	157.0	6287.2	480
7	Old pine	1.1	70.0	77	5390	75.8	5297.5	486
8	Pine	5.0	30.0	150	4500	151.9	4869.9	482
9	Hardwood	2.0	20.0	40	800	40.6	896.0	200
10	Lowlands	4.0	5.0	20	100	19.7	96.4	59
11	R.R.	2.0	30.0	60	1800	59.9	1799.3	286
12	R.R.	2.0	30.0	60	1800	59.9	1799.3	286
13	R.R.	3.0	30.0	90	2700	90.2	2674.5	308
14	R.R.	3.0	30.0	90	2700	90.2	2674.5	308
15	R.R.	1.0	20.0	20	400	20.9	434.3	169
16	Camp	2.0	20.0	40	800	40.6	896.0	200
17	Road	3.0	20.0	60	1200	60.6	1248.5	261
18	Road	3.0	20.0	60	1200	60.6	1248.5	261
19	Road	.25	40.0	10	400	9.9	394.9	234
20	Dump	2.0	160.0	320	31200	323.0	51640.	1539

Table means and maximum values in acres.

Table III-1.

FIRE SIZE PROBABILITY DISTRIBUTIONS

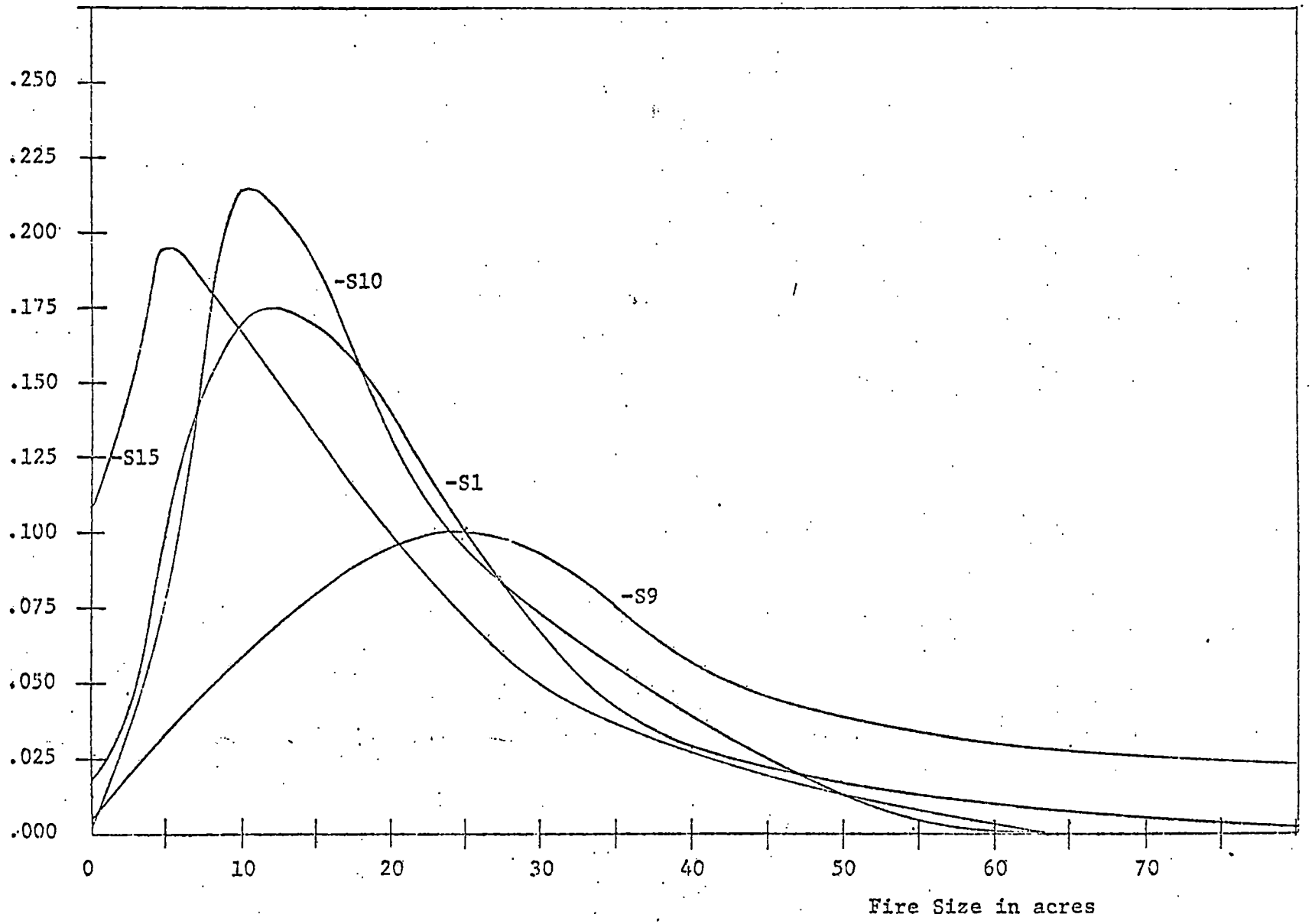


Figure III-1.

FIRE SIZE PROBABILITY DISTRIBUTIONS

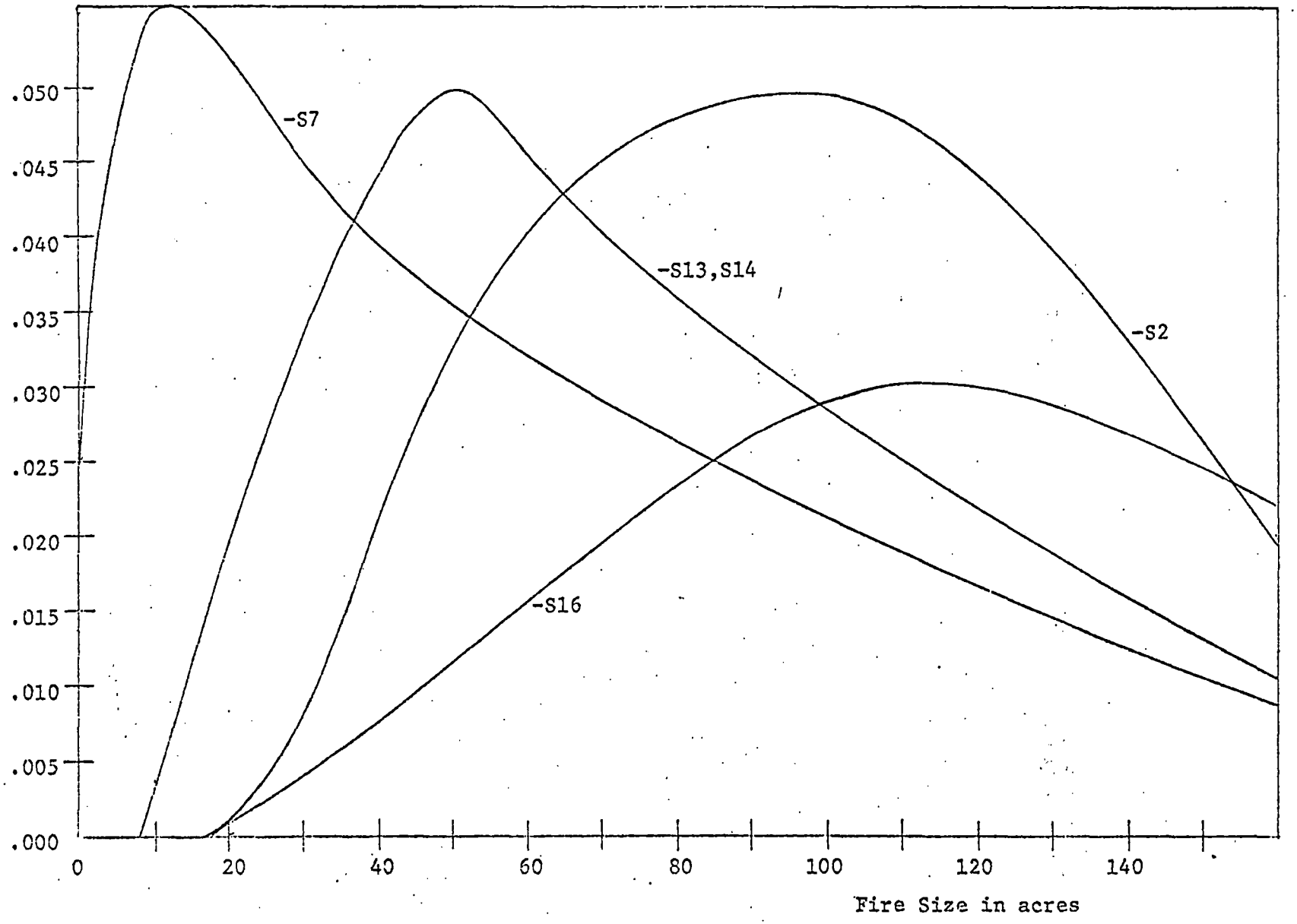


Figure III-2.

FIRE SIZE PROBABILITY DISTRIBUTIONS

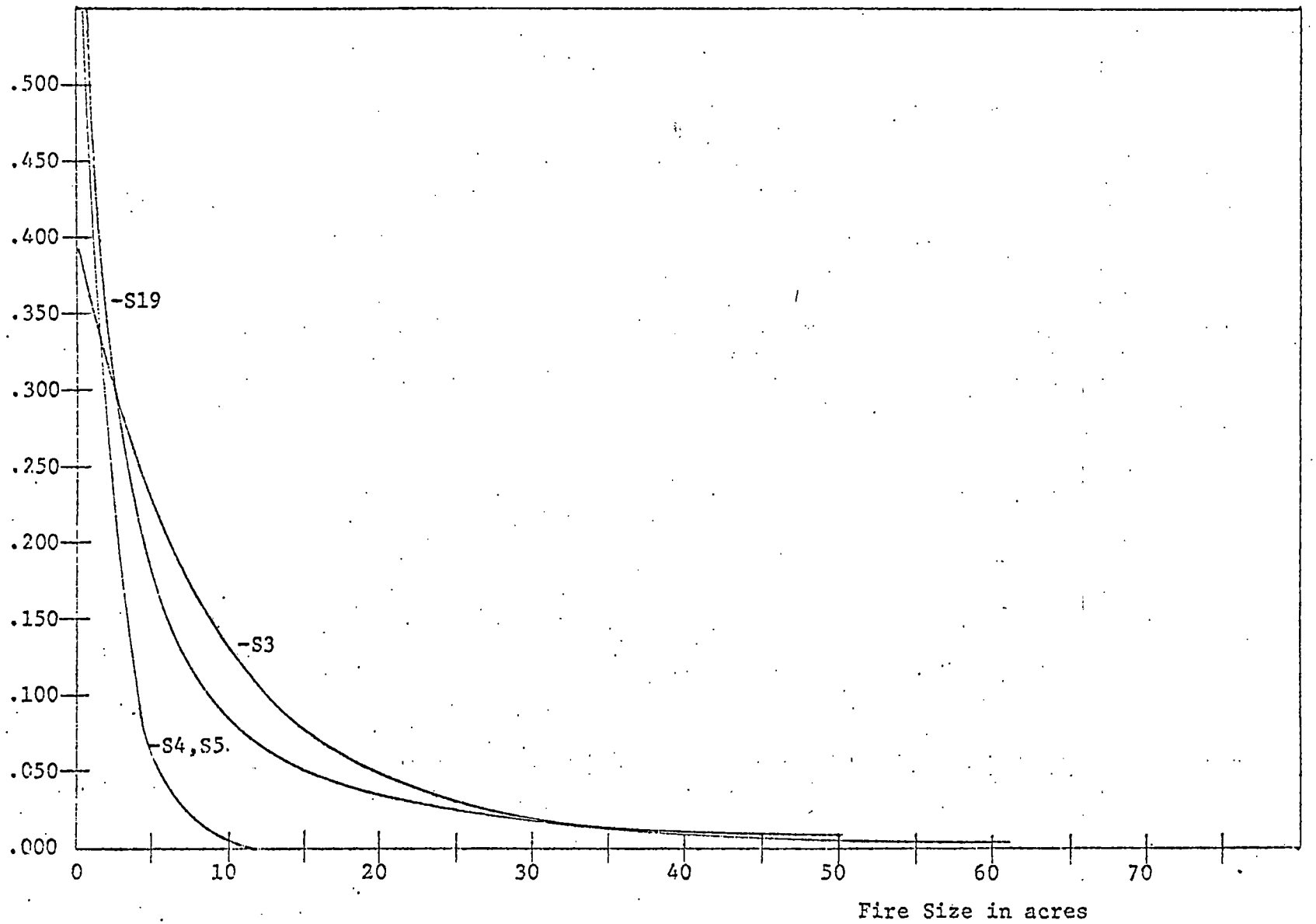


Figure III-3.

APPENDIX IV

MONTE CARLO PROCEDURE PROGRAM DESCRIPTIONS AND LISTINGS

The program IV-1 simulates 2000 fires using the function GAM (Appendix V). It also calculates the mean and variance of the sample, and prints them out along with the size of the largest fire in the sample.

The program IV-2 is program IV-1 modified to read in the range to the nearest fire station and to reduce the fire sizes as is done in the Main program.

Both programs must be compiled with the function GAM or a substitute with the name GAM. The programs use the output device 6 for printing the means and variances, and the output device 7 for printing or filing the random variates.

```
C      G A M M A   G E N E R A T E R   T E S T E R
C      COMPILE WITH GAMMA FUNCTION
C      I/O DEVICES INPUT=5,VARIATE OUTPUT=7,SUMMARY OUTPT=6
C
       REAL MIN,MAX
       DIMENSION X(10)
       ISEED=0
       MIN=0.
       MAX=0.
       SUMX=0.
       SUMX2=0.
       IT=100
C
       READ(5,105) A,B
  105  FORMAT(2F10.3)
       DO 300 I=1,IT
       DO 200 J=1,10
       X(J)=GAM(B,A,ISEED)
       IF(X(J).GT.MAX) MAX=X(J)
       IF(X(J).LT.MIN) MIN=X(J)
       SUMX=SUMX+X(J)
       SUMX2=SUMX2+X(J)**2
  200  CONTINUE
       WRITE(7,215)(X(J),J=1,10)
  215  FORMAT(10F10.4)
  300  CONTINUE
       XN=IT*10.
       XBAR=SUMX/XN
       VARX=(SUMX2-SUMX**2/XN)/(XN-1.)
       WRITE(6,225) A,B,XBAR,VARX,MAX,MIN
  225  FORMAT('0 ALPHA=',F10.3,'  BETA=',F10.3
     *,/' MEAN=',F10.2,'  VARIANCE=',F10.2//
     *,'  MAXIMUM ',F12.3,',  MINIMUM ', F12.6//)
       RETURN
       END
```

Program IV-1

```
    G A M M A   G E N E R A T E R   T E S T E R
    COMPILE WITH GAMMA FUNCTION
    I/O DEVICES INPUT=5,VARIATE OUTPUT=7,SUMMARY OUTPT=6

    REAL MIN,MAX
    DIMENSION SIZE(10)
    ISEED=0
    MIN=0.
    MAX=0.
    SUMX=0.
    SUMX2=0.
    IT=200

    READ(5,105) A,B,RANGE
105 FORMAT(3F10.3)
    DO 300 I=1,IT
    DO 200 J=1,10
    SIZE(J)=GAM(B,A,ISEED)
    SIZE(J)=SIZE(J)*AMIN1(0.015*RANGE+0.2,1.0)
    IF(SIZE(J).GT.MAX) MAX=SIZE(J)
    IF(SIZE(J).LT.MIN) MIN=SIZE(J)
    SUMX=SUMX+SIZE(J)
    SUMX2=SUMX2+SIZE(J)**2
200 CONTINUE
    WRITE(7,215)(SIZE(J),J=1,10)
215 FORMAT(10F10.4)
300 CONTINUE
    XN=IT*10.
    XBAR=SUMX/XN
    VARX=(SUMX2-SUMX**2/XN)/(XN-1.)
    WRITE(6,225) A,B,XBAR,VARX,MAX,RANGE
225 FORMAT('0 ALPHA=',F10.3,'  BETA=',F10.3
   *,/' MEAN=',F10.2,'  VARIANCE=',F10.2//
   *,'  MAXIMUM ',F12.3,',  RANGE ', F12.6//)
    RETURN
```

Program IV-2

APPENDIX V

PROGRAMMER'S GUIDE

TO

FLASH FIRE

This section of the Guide to Flash Fire contains the guide, the Main program listing, and the subroutine listings. This text was computer produced and the numbers in the upper right hand corner is the guide section number.

PROGRAMMER'S GUIDE

SETTING UP THE PROGRAM

The user is provided with a source program, in FORTRAN IV, which must be compiled; the resultant object program must be stored in a file before running the game.

NECESSARY FILES

The object program may be stored in one file of moderate size. A suitable name for this file would be FLASHFIRE.

SUBROUTINE DESCRIPTIONS

REPLY returns information from a line of text offered by the user. It extracts a codeword, if any, and up to ten numbers. Faulty data input can be checked and the user so informed without terminating the program.

GAUSS returns a normally distributed random number. It calls upon a uniform random number generator, URAND, which IS UNIQUE TO THE COMPUTER. Therefore, the user must replace any and all calls to URAND with equivalent calls to his systems's uniform random number generator or add a dummy function URAND which then calls his system's uniform number generator. Such a function might look like

```
      FUNCTION URAND(ISEED)
      URAND=RANF(ISEED)
      RETURN
      END
```

where RANF would be the name of the user's uniform number generator.

IT is a simple subroutine to vary the order of occurrence of comments. It selects a comment randomly and reduces the probability of picking that comment again to 0. When all comments have been used up their probabilities are restored to nonzero values.

SPECIAL PROGRAM FEATURES

The only special features are the use of REPLY to input data and the facility to inspect program values via the instructor mode.

LISTING OF THE PROGRAM

```
C
C                     F L A S H   F I R E   I I
C     ***************************************************************
C                   VARIABLE DICTIONARY
C     ALTER
```

```
C     AGE()          AGE OF FIRE STATION()
C     ACRES          PROPOSED AREA TO BE MODIFIED
C     ANSWER         NUMERIC ANSWER RETURNED BY SUBROUTINE REPLY
C     AREA()         AN ARRAY CONTAINING THE VARIOUS STRATA AREAS
C     ARGUE          ANY OF THREE ARGUEMENTS TO THE REPLY SUBROUTINE
C                    LISTING THE KEYORDS
C     BUDGET         THE AMOUNT THAT YOU HAVE ALLOCATED IN ANY PART OF
C                    THE PROGRAM
C     BLOCK          INDEX INDICATING THE SPECIAL TREATMENT BLOCK NO.
C     BOUND( , )     STRATA BOUNDARY; CHECK BOUNDARY CONVENTION
C     BURNED         AREA, IN ACRES, BURNED IN A PARTICULAR FIRE
C     CHANCE         COUNTER, SUMMING NUMBER OF TIMES THE PLAYER EXCEEDS
C                    CUT(3), 3 TIMES AND THE PLAYER IS FIRED
C     CHANGE         A 3 ELEMENT VECTOR REPRESENTING THE FRACTION OF RE-
C                    DUCTION IN FIRE PROBABILITY/ACRE/YEAR AS DETERMINED
C                    BY THE STRATEGIC DECISIONS
C     CLASS          SIZE CLASS OF THE FIRE: A,B,C OR D
C     COST           COST OF CONTROLLING THE FIRE
C     CUT()          CUTOFF TOTAL COST PLUS LOSS IN COMMENT SELECTION
C     DAMAGE()       STORED COST+LOSS DAMAGE FIGURE
C     SPENT()        COST OF THAT PARTICULAR DECISION
C     GAP            DISTANCE FROM A FIRE START TO THE NEAREST STATION
C     EFFECT( , )    A 5 X 20 MATRIX CONTAINING THE DEGREE WHICH
C                    STRATA OR BLOCK WILL BE AFFECTED BY WHICH STRATEGY
C     ENTRY          COUNTER INDEXING ANSWER NUMBER RETURNED BY REPLY
C     EXPECT( )      EXPECTED NUMBER OF FIRES IN A STRATA
C     FINALA         AN ACCUMULATOR OF ACRES BURNED FOR THE FINAL SUMMARY
C     FINALC         SAME FOR COST+LOSS
C     FINALN         SAME FOR NUMBER OF FIRES
C     FIRES          THE EXPECTED NUMBER OF FIRES IN A STRATA
C                    PRODUCED BY MODIFYING EXPECT BY STRATEGY
C     HAZARD( )      THE NUMBER OF ACRES THAT CAN EFFECTIVELY
C                    BE REDUCED IN HAZARD BY FUEL MODIFICATION
C     GOTTEN         NUMBER OF ANSWERS RETURNED BY REPLY
C     HOME( , )      THE COORDINATES OF DEVELOPMENTS OF HIGH VALUE OR
C                    POINTS OF PUBLIC ATTENTION
C     IDENT          AN ARRAY CONTAINING THE STRATA NUMBER THAT IS USED
C                    TO LOCATE THE FIRE STARTS FROM THE BLOCK SOURCES
C     LIMIT          ACREAGE LIMIT FOR A FIRE CLASS SIZE
C     LOCALE(X,J)    THE X COORDINATE OF A FIRE STATION # J
C     LOCALE(Y,J)    THE Y COORDINATE OF A FIRE STATION # J
C     LOSS           PROPERTY DAMAGE BASED ON VALUE PER ACRE
C     MARK           FLAG FOR THE 10 YEAR SUMMARY
C     MAX()          MAXIMUM ACREAGE LIMIT FOR A FIRE CLASS
C     METHOD         METHOD OF FUEL MODIFICATION
C     MODIFY( , )    AREA IN STRATA TO BE MODIFIED BY METHOD BURN OR
C                    CRUSH; FOR FIREBREAKS IT WILL=1 IF A BREAK IS
C                    SELECTED
C     NAME()         AN ARRAY CONTAINING THE VARIOUS INPUT LABELS
C     NCELLS         NUMBER OF CELLS THE FIRE HAS SPREAD TO
C     NFIRES         NUMBER OF FIRE STARTS IN THE STRATA
C     NUMBER         TEMPORARY STORAGE FOR NUMBER OF FIRES
```

```
C     PLAN          THE STRATEGY BEING EVALUATED: E.G. BILLBOARDS
C     PDAMAG        PROJECTED ACCUMULATED DAMAGE FOR 50 YEARS
C     PRICE()       UNIT PRICE FOR DECISIONS
C     FIRE()        A 20 ELEMENT MATRIX, FIRST CONTAINING THE INITIAL
C                   PROBABILITY OF A FIRE START IN EACH STRATA AND BLOCK
C     PSIZE         PROJECTED ACCUMULATED SIZE FOR 50 YEARS
C     REMAIN        REMAINING BURNED ACREAGE IN DAMAGE CALCULATION
C     SCALE         AN ARRAY CONTAINING THE SCALE PARAMETERS FOR EACH
C                   SOURCE GAMMA DISTRIBUTION.
C     SHAPE         LIKEWISE FOR SHAPE PARAMETERS
C     SIZE          SIZE OF THE FIRE IN ACRES
C     STRATA        THE NUMBER OF A STRATA
C     STORE         USED FOR THE TEMPORARY STORAGE OF A VARIABLE
C     SUM           THE SUM MENTIONED IN THE REDUCTION COEFFICIENT
C     TDAMAG        ACCUMULATED COST PLUS LOSS
C     TIMER         NUMBER OF TIMES THE PROGRAM HAS GONE THROUGH THE
C                   ONE YEAR CYCLE
C     TSIZE         ACCUMULATED AREA BURNED BY STRATA
C     TOTAL         TOTAL ACCUMULATED DAMAGES FOR THE YEAR
C     UNITS()       NUMBER OF UNITS SELECTED FOR A PARTICULAR STRATEGY
C     VALUE()       VALUE AT RISK PER ACRE
C     WORD          KEYWORD RETURNED BY SUBROUTINE REPLY
C     X,YCOORD      X AND Y COORDINATES OF A FIRE START, TEMPORARY
C     XSTART        XCOORDINATE OF A PARTICULAR FIRE, PERMANENT
C     YSTART        YCOORDINATE OF A PARTICULAR FIRE
C     ***************************************************************
C
C
C                CELL NUMBERING CONVENTION
C
C          1 2 3 4 5 6 7 8 . . .100
C          2
C          3     N
C          4   W E
C          5     S
C          6
C
C          BOUND/N,E,S,W
C
C
C     ***************************************************************
C
C     THIS PROGRAM USES THE IBM 360/67 UNIFORM RANDOM NUMBER GENERATOR,
C     URAND. FOR USE ON OTHER SYSTEMS, IT IS NECESSARY TO DEFINE A
C     FUNCTION URAND TO CALL YOUR LOCAL GENERATING FUNCTION AND RETURN
C     A UNIFORM RANDOM NUMBER BETWEEN 0 AND 1.
C
C     AN AMPERSAND IS USED IN FORMATS TO SUPPRESS LINE FEEDS. AN
C     EQUIVALENT CHARACTER OR A BLANK MAY REPLACE IT.
C
C     ***************************************************************
      REAL ANSWER(20)
```

```
*     ,AREA(10)
*     ,BURNED(10,150)
*     ,CUT(3)
*     ,DAMAGE(10,150)
*     ,EFFECT(20,6)
*     ,EXPECT(20)
*     ,FIRES(20)
*     ,HAZARD(20)
*     ,LOSS
*     ,MAX(5)
      REAL P1(5)
*     ,P2(5)
*     ,P3(3)
*     ,PRICE(20)
*     ,SHAPE(20)
*     ,SCALE(20)
*     ,SPENT(10)
*     ,TDAMAG(10,5)
*     ,TSIZE(10,5)
*     ,VALUE(20)
      INTEGER A,B,C,D,E
*        ,ADD
*        ,AGE(10)
*        ,ARGUE1(45)
*        ,ARGUE2(9)
      INTEGER ARGUE3(13)
*        ,ARGUE4(26)
*        ,BLANK
*        ,BLOCK
*        ,BOUND(4,20)
*        ,CHANCE
*        ,CLASS
*        ,DATE(3)
*        ,DEL
*        ,DUMMY
*        ,ENTRY
*        ,FIRE
*        ,GOTTEN
*        ,HOME(2,5)
*        ,IDENT(10)
*        ,LOCALE(4,10)
      INTEGER MARK
*        ,METHOD
*        ,MODIFY(3,20)
*        ,NCELLS
*        ,NORTH,EAST,SOUTH,WEST
*        ,NO
*        ,NFIRES
*        ,NUMBER
*        ,ONE
*        ,PLAN
*        ,SKIP
```

```
*        ,SOURCE
*        ,STORE
*        ,STRATA
*        ,TOP,RIGHT,BOTTOM,LEFT
*        ,TOWERS
 INTEGER TEN
*        ,TIMER
*        ,TOTAL(10)
*        ,TRACT
*        ,TRY
*        ,UNITS(7)
*        ,USED(5)
*        ,WORD
*        ,X,Y
*        ,XCOORD,YCOORD
*        ,YEAR
*        ,YES
*        ,YSTART(10,100)
*        ,XSTART(10,100)
 DATA AREA/192E3,128E3,96E3,8E4,54E3,144E3,384E3,192E3,128E3,192E3/
 DATA ARGUE1/2,1HB,1HI
*           ,2,1HC,1HO
*           ,2,1HR,1HA
*           ,2,1HB,1HU
*           ,2,1HC,1HR
*           ,2,1HB,1HR
*           ,2,1HS,1HT
*           ,1,1HH
*           ,1,1HV
*           ,2,1HP,1HR
*           ,2,1HG,1HO
*           ,3,1HF,1HI,1HN
*           ,2,1HE,1HX
*           ,2,1HD,1HE
*           ,2,1HI,1HN,0/
*    ,ARGUE2/1,1HD
*           ,1,1HA
*           ,1,1HY
*           ,1,1H ,0/
 DATA ARGUE3/1,1HA
*           ,1,1HB
*           ,1,1HC
*           ,1,1HD
*           ,1,1HE
*           ,1,1H
*           ,0/
 DATA ARGUE4/2,1HS,1HI
*           ,2,1HC,1HL
*           ,2,1HE,1HX
*           ,3,1HN,1HO,1HE
*           ,3,1HN,1HO,1HB
*           ,2,1HB,1HU
```

```
     *            ,2,1HC,1HU
     *            ,1,1H ,0/
C
C       THIS SECTION CONTAINS THE STRATA BOUNDARIES.  THEY MAY BE
C       ALTERED TO FIT ANY STRATA CONFIGURATION WITHOUT REQUIRING
C       FURTHER CHANGES IN THE PROGRAM
C
      DATA BOUND/  1, 40, 30,  1
     *           ,  1, 60, 40, 41
     *           ,  1, 90, 20, 61
     *           ,  1,100, 50, 91
     *           , 31, 40, 40,  1
     *           , 21, 90, 50, 61
     *           , 41, 60, 80,  1
     *           , 51,100, 80, 61
     *           , 81, 40,100,  1
     *           , 81,100,100, 41
     *           ,  1, 60, 20, 60
     *           , 21, 60, 40, 60
     *           , 41, 60, 60, 60
     *           , 61, 60, 80, 60
     *           , 81, 60,100, 60
     *           , 89, 31, 91, 29
     *           , 41, 90, 41, 61
     *           , 41, 60, 41, 31
     *           , 41, 30, 41,  1
     *           , 29, 87, 32, 83/
C
C       THIS SECTION CONTAINS THE NUMBER OF ACRES OF FUEL THAT
C       REQUIRES MODIFICATION IN EACH STRATA EACH YEAR.  IT CAN BE
C       CHANGED TO FIT LOCAL CONFIGURATIONS AND THE MODEL WILL
C       HANDLE IT.
C
      DATA HAZARD/0.,400.,3*0.,5E2,800.,3[illegible],2*100.,10*1./
     *    ,PRICE/5E2,1E3,5E3,100.,150.,5E3,5E4,5E2,2*1E4,10*5E3/
C
C       THE VALUE PER ACRE VECTOR, EFFECT MATRIX, AND EXPECT
C       VECTOR MAY BE MODIFIED WITHOUT AFFECTING THE MODEL.
C
      DATA VALUE/200.,50.,400.,28000.,18000.,25.,100.,300.,400.,50.
     *          ,50.,50.,150.,150.,50.,400.,1500.,50.,1000.,25./
     *    ,EFFECT/16*0.001,3*0.04,0.0
     *           ,3*0.001,0.0005,0.001,0.0005,4*0.001,9*0.0005,0.001
     *           ,0.01,0.001,0.01,0.001,0.010,3*0.001,0.01,7*0.001
     *           ,3*0.005,0.01
     *           ,0.0,0.5,3*0.0,3*0.9,12*0.0
     *           ,5*0.0,3*1.0,12*0.0
     *           ,10*0.0,0.5,1.0,0.9,2*0.5,5*1.0/
     *    ,EXPECT/4.,6.,4.,2.,2.,6.,20.,10.,6.,4.
     *           ,2.,10.,10.,2.,2.,6.,4.,4.,4.,10./
      DATA   MAX/0.0,0.25,10.,100.,300./
     *    ,HOME/42,35
```

```
*          ,65,41
*          ,55,80
*          ,30,85
*          ,21,90/
*     ,SHAPE/2.0,6.0,0.5,2*0.055,4.0,1.1,5.0,2.0,4.0
*           ,2.0,2.0,3.0,3.0,1.0,2.0,3.0,3.0,.25,2.0/
*     ,SCALE/10.,20.,20.,2*40.,40.,70.,30.,20.,5.0
*           ,30.,30.,30.,30.,20.0,20.,20.,20.,40.,150./
*     ,ADD/2/
 DATA A/1/
*     ,AGE/10*0/
*     ,B/2/
*     ,BLANK/3/
*     ,BOTTOM/3/
*     ,C/3/
*     ,CHANCE/0/
*     ,CUT/750000.,850000.,1150000./
*     ,D/4/
 DATA DEL/1/
*     ,E/5/
*     ,EAST/2/
*     ,FINALA/0.0/
*     ,FINALC/0.0/
*     ,FINALN/0.0/
*     ,ISEED/69/
*     ,IDENT/2,2,7,7,10,9,6,7,7,6/
*     ,INIT/1/
*     ,LEFT/4/
*     ,MATRIX/1/
 DATA MODIFY/60*0/
*     ,NO/1/
*     ,NORTH/1/
*     ,NUMBER/0/
*     ,ONE/1/
 DATA P1/5*.2/
*     ,P2/5*.2/
*     ,P3/3*.33333/
*     ,RIGHT/2/
*     ,SKIP/1/
*     ,SOUTH/3/
*     ,SPENT/10*0.0/
*     ,TOWERS/7/
*     ,TEN/2/
*     ,TIMER/0/
*     ,TOP/1/
*     ,UNITS/7*0/
*     ,USED/5*1/
*     ,WEST/4/
*     ,YES/2/
*     ,X/1/
*     ,Y/2/
 DO 10 SOURCE=1,20
```

```
      MODIFY(3,SOURCE)=1
   10 CONTINUE
      WRITE(7,15)
   15 FORMAT(1H-,18X,32H*** F L A S H   F I R E   II ***//)
      WRITE(6,25)
   25 FORMAT(39H8 DO YOU WANT A DESCRIPTION, YES OR NO?)
      CALL REPLY(ARGUE2,WORD,ANSWER,GOTTEN)
      IF(WORD.NE.3) GO TO 50
      WRITE (6,??)
C
C     THIS SUMMARY IS NOT NECESSARY FOR PLAYERS HAVING A MANUAL
C
   35 FORMAT(51H0     FLASH FIRE IS A GAME TO ACQUAINT YOU WITH THE,18H
     1RUDIMENTS OF FIRE/ 36H CONTROL PLANNING. YOUR OBJECTIVE IS,30H TO
     2MINIMIZE THE TOTAL COST OF/ 17H FIRE PROTECTION,,52H SUPPRESSION,
     3AND DAMAGES IN THE BEAVER BELLY FOREST/ 48H DISTRICT.  THIS IS AN
     4AREA OF HIGH FIRE DANGER ,17H CHARACTERIZED BY/ 35H LOGGING, RAILR
     5OAD, RECREATION, AND,34H SOME "SET" FIRES.  THE PLAYER HAS/ 21H A
     6BUDGET OF $500,000,43H WITH WHICH TO FINANCE THE VARIOUS STRATEGY/
     7,12H INPUTS WITH,57H WHICH HE WILL ATTEMPT TO REDUCE BOTH OCCURREN
     8CE AND SIZE/ 61H OF WILDFIRE ON THE DISTRICT.  THE FOLLOWING ARE D
     9ESCRIPTIONS,7H OF THE/ 22H STRATEGIES AVAILABLE:)
      WRITE(6,36)
   36 FORMAT(22H0 KEYWORD; DESCRIPTION/ 25H BILLBOARDS; STRATEGICALLY,38
     1H LOCATED BILLBOARDS OR VISUAL FIRE/ 21H   PREVENTION DEVICES/ 55H
     2 CONTACTS; SERIES OF 5 PUBLIC INFORMATION AND EDUCATION,10H MEETIN
     3GS./ 44H RADIO ANNOUNCEMENTS; PURCHASE INCLUDES FIVE,17H SPOTS AN
     4OUNCING/ 39H   FIRE DANGER & PUBLIC EDUCATION INFO./ 59H BURNING;
     5RUSHING; FUEL MODIFICATION OF SLASH AND AREAS OF,10H HAZARDOUS/ 48
     6H   FUELS. ASSUME THAT BY SELECTING THIS STRATEGY,23H , THE OPTIMU
     7M LOCATION/ 31H   FOR BURNING WILL BE SELECTED/ 59H BREAKS; FIRE B
     8REAKS ARE ESTABLISHED AND MAINTAINED FOR ONE/ 61H   YEAR IN ANY ON
     9E OF 10 PREDEFINED BLOCKS.  THESE BLOCKS ARE,3H LOCATED/ 48H   IN
     1AREAS OF KNOWN HIGH FIRE PROBABILITY.  YOU,21H MUST SELECT A WHOLE
     2 / 34H   BLOCK IN ORDER TO MAKE THE WORK,23H ECONOMICALLY FEASIBLE
     3./ 33H STATION; A FIRE STATION WITH ONE,37H TRUCK.  THIS COST IS T
     4OR A FIVE YEAR/ 15H   PERIOD.  ONCE,56H ESTABLISHED, THE STATION CA
     5NNOT BE DELETED OR RELOCATED/ 29H   FOR FIVE RUNS OF THE GAME./ 28
     6H VALUE AT RISK; A PROFESSION,42HALLY PREPARED SURVEY OF THE EXPEC
     7TED VALUE/ 12H   REDUCTION,58H DUE TO WILDFIRE ON A PER ACRE BASIS
     8.  REMEMBER, FIRE DOES/ 43H   NOT NECESSARILY CAUSE TOTAL DESTRUCT
     9ION.)
      WRITE(6,38)
   38 FORMAT(11H HISTORY; A,53H QUALITATIVE LISTING OF THE AREAS OF INIT
     1NTIAL DANGER/ 49H   BASED ON RECORDS AND MEMORY OF PREVIOUS YEARS.
     2)
      WRITE(6,37)
   37 FORMAT(17HOOUTPUT AVAILABLE/ 30H YEARLY SUMMARY:  PRODUCED AUTO,3HA
     1MATICALLY AND CONTAINS THE COST+LOSS/ 14H SUMMARIZED BY,47H STRATA
     2 AND FIRE CLASS.  TOTAL FIRES PER STRATA/ 7H APPEAR,56H IN PARENTH
     3ESES.  TOTAL COST+LOSS INCLUDES YEARLY BUDGET// 56H DETAILS:  UPON
     4GIVING THE KEYWORD DETAILS FOLLOWED BY A ,14H STRATA NUMBER/ 22H
```

```
      MODIFY(3,SOURCE)=1
   10 CONTINUE
      WRITE(7,15)
   15 FORMAT(1H-,18X,32H*** F L A S H   F I R E   II ***//)
      WRITE(6,25)
   25 FORMAT(39H& DO YOU WANT A DESCRIPTION, YES OR NO?)
      CALL REPLY(ARGUE2,WORD,ANSWER,GOTTEN)
      IF(WORD.NE.3) GO TO 50
      WRITE (6,??)
C
C     THIS SUMMARY IS NOT NECESSARY FOR PLAYERS HAVING A MANUAL
C
   35 FORMAT(51H0      FLASH FIRE IS A GAME TO ACQUAINT YOU WITH THE,13H
     1RUDIMENTS OF FIRE/ 36H CONTROL PLANNING. YOUR OBJECTIVE IS,30H TO
     2MINIMIZE THE TOTAL COST OF/ 17H FIRE PROTECTION,,52H SUPPRESSION,
     3AND DAMAGES IN THE BEAVER BELLY FOREST/ 48H DISTRICT.  THIS IS AN
     4AREA OF HIGH FIRE DANGER ,17H CHARACTERIZED BY/ 35H LOGGING, RAILR
     5OAD, RECREATION, AND,34H SOME "SET" FIRES.  THE PLAYER HAS/ 21H A
     6BUDGET OF $500,000,43H WITH WHICH TO FINANCE THE VARIOUS STRATEGY/
     7,12H INPUTS WITH,57H WHICH HE WILL ATTEMPT TO REDUCE BOTH OCCURREN
     8CE AND SIZE/ 61H OF WILDFIRE ON THE DISTRICT.  THE FOLLOWING ARE D
     9ESCRIPTIONS,7H OF THE/ 22H STRATEGIES AVAILABLE:)
      WRITE(6,36)
   36 FORMAT(22H0 KEYWORD; DESCRIPTION/ 25H BILLBOARDS; STRATEGICALLY,34
     1H LOCATED BILLBOARDS OR VISUAL FIRE/ 21H   PREVENTION DEVICES/ 55H
     2 CONTACTS; SERIES OF 5 PUBLIC INFORMATION AND EDUCATION,10H MEETIN
     3GS./ 44H RADIO ANNOUNCEMENTS; PURCHASE INCLUDES FIVE,17H SPOTS W
     4OUNCING/ 39H   FIRE DANGER & PUBLIC EDUCATION INFO./ 58H BURNIN
     5RUSHING; FUEL MODIFICATION OF SLASH AND AREAS OF,10H HAZARDOUS/ 48
     6H   FUELS. ASSUME THAT BY SELECTING THIS STRATEGY,23H , THE OPTIMU
     7M LOCATION/ 31H   FOR BURNING WILL BE SELECTED/ 59H BREAKS; FIRE B
     8REAKS ARE ESTABLISHED AND MAINTAINED FOR ONE/ 61H   YEAR IN ANY ON
     9E OF 10 PREDEFINED BLOCKS.  THESE BLOCKS ARE,8H LOCATED/ 48H   IN
     1AREAS OF KNOWN HIGH FIRE PROBABILITY.  YOU,21H MUST SELECT A WHOLE
     2 / 34H  BLOCK IN ORDER TO MAKE THE WORK,23H ECONOMICALLY FEASIBLE
     3./ 33H STATION; A FIRE STATION WITH ONE,37H TRUCK.  THIS COST IS F
     4OR A FIVE YEAR/ 15H   PERIOD.  ONCE,56H ESTABLISHED, THE STATION CA
     5NNOT BE DELETED OR RELOCATED/ 29H   FOR FIVE RUNS OF THE GAME./ 22
     6H VALUE AT RISK; A PROFESSION,42HALLY PREPARED SURVEY OF THE EXPEC
     7TED VALUE/ 12H   REDUCTION,58H DUE TO WILDFIRE ON A PER ACRE BASIS
     8.  REMEMBER, FIRE DOES/ 43H   NOT NECESSARILY CAUSE TOTAL DESTRUCT
     9ION.)
      WRITE(6,38)
   38 FORMAT(11H HISTORY; A,53H QUALITATIVE LISTING OF THE AREAS OF PAST
     1NTIAL DANGER/ 49H  BASED ON RECORDS AND MEMORY OF PREVIOUS YEARS.
     2)
      WRITE(6,37)
   37 FORMAT(17H0OUTPUT AVAILABLE/ 30H YEARLY SUMMARY:  PRODUCED AUTO,3H
     1MATICALLY AND CONTAINS THE COST+LOSS/ 14H SUMMARIZED BY,47H STRATA
     2 AND FIRE CLASS.  TOTAL FIRES PER STRATA/ 7H APPEAR,56H IN PARENTH
     3ESES.  TOTAL COST+LOSS INCLUDES YEARLY BUDGET// 56H DETAILS: UPON
     4GIVING THE KEYWORD DETAILS FOLLOWED BY A ,14H STRATA NUMBER/ 42H
```

```
     5HE PROGRAM QUERIES FOR THE MINIMUM CLASS,23H.  INFORMATION INCLUDE
     6S/ 31H COORDINATES,SIZE,AND COST+LOSS,10H PER FIRE.//45H TEN YEAR
     7PROJECTION: UPON GIVING THE KEYWORD,23H PROJECTION AN EXPECTED/ 30
     8H YEARLY AVERAGE OF AREA BURNED AND,30H TOTAL COST+LOSS IS CALCULA
     9TED/ 27H NOTE ON FIRE CLASSES: A;0-,30H.25,B;.26-10,C;10-99,D;100-
     1299// 27H      THE PROTOTYPE OF THIS,41H GAME WAS DEVELOPED IN 197
     21 BY THE SCHOOL/ 11H OF NATURAL,54H RESOURCES, THE UNIVERSITY OF M
     3ICHIGAN, ANN ARBOR WITH/ 63H SUPPORT AND COOPERATION FROM THE NAT
     4IONAL SCIENCE FOUNDATION.,/56H  FURTHER DEVELOPMENT TO PRESENT FOR
     5M WAS DONE IN 1972-3,14H BY THE SCHOOL/ 39H OF NATURAL RESOURCES W
     6ITH SUPPORT AND,31H COOPERATION OF THE U.S. FOREST/ 22H SERVICE NO
     7RTH CENTRAL,27H FOREST EXPERIMENT STATION.///////)
      GO TO 60
   50 WRITE(6,55)
   55 FORMAT(24H& PRICE LIST, YES OR NO?)
      CALL REPLY(ARGUE2,WORD,ANSWER,GOTTEN)
      IF(WORD.NE.3) GO TO 110
   60 WRITE(6,65) (PRICE(WORD),WORD=1,10)
   65 FORMAT(22H0  P R I C E   L I S T// 13H BILLBOARDS $,F5.0,5H$A/YR,1
     13H   CONTACTS $,F6.0,5H/5/YR/ 13H RADIO ANN. $,F6.0,5H/5/YR,13H
     2BURNING  $,F6.0,5H/A/YR/ 13H CRUSHING   $,F6.0,5H/A/YR,13H   BREAK
     3    $,F6.0,5H$A/YR/ 12H STATION   $,F7.0,21H/A/YR, FOR FIVE YEARS/
     4,18H HISTORY OF FIRE $,F6.0,13H  VALUE AT RISK $,F6.0/ 13H PROJEC
     5TION $,F6.0//////)
C     **********************************************************************
C
C START STRATEGY INPUTS
C
  110 WRITE(6,115)
  115 FORMAT(15H ENTER STRATEGY)
  120 WRITE(6,125)
  125 FORMAT(2H&?)
      TRY=0
      CALL REPLY(ARGUE1,WORD,ANSWER,GOTTEN)
      DO 134 ENTRY=1,GOTTEN
      IF(ANSWER(ENTRY).GT.-0.9) GO TO 134
      WRITE(6,133)
  133 FORMAT(28H NO NEGATIVE NUMBERS ALLOWED)
      GO TO 120
  134 CONTINUE
      IF (WORD.GT.0) GO TO 130
      WRITE(6,135)
  135 FORMAT(16H INVALID KEYWORD)
      GO TO 120
  130 IF(WORD.GT.5) GO TO 150
      IF(GOTTEN.GT.0) GO TO(210,210,210,220,220),WORD
      WRITE(6,137)
  137 FORMAT(30H NUMERICAL INFORMATION MISSING)
      GO TO 120
  150 JUMP=WORD-5
      GO TO(400,300,390,396,1100,600,1300,1300,460,1200),JUMP
  160 SPENT(WORD)=PRICE(WORD)*UNITS(WORD)
```

```
C
C       THE PROGRAM RECALCULATES THE ENTIRE BUDGET ALLOCATION EACH
C       TIME IT REACHES THIS POINT.  THIS IS TO ACCOMODATE ALL OF THE
C       POSSIBLE CHANGES, ADDITIONS, ETC. THAT MAY BE SELECTED.
C
  170 BUDGET=0.0
      DO 180 WORD=1,10
      BUDGET=BUDGET + SPENT(WORD)
  180 CONTINUE
      WRITE (6,185) BUDGET
  185 FORMAT(10H BUDGET =$,F8.0)
      GO TO 120
C
C INPUT ADVERTISING UNITS,PREVENTION CONTACTS AND RADIO ANNOUNCEMENTS
C
  210 UNITS(WORD)=ANSWER(1)
      GO TO 160
C
C  FUEL MODIFICATIONS
C
  220 IF((GOTTEN/2)*2 .EQ. GOTTEN) GO TO 230
      WRITE(6,225)
  225 FORMAT(30H NUMERICAL INFORMATION MISSING)
      GO TO 120
  230 METHOD=WORD-3
      DO 260 ENTRY=2,GOTTEN,2
      STRATA=ANSWER(ENTRY-1)+.1
      IF (STRATA.GE.1 .AND. STRATA.LE.10) GO TO 240
      WRITE(6,237) STRATA
  237 FORMAT(9H STRATA #,I3,15H DOES NOT EXIST)
      GO TO 260
  240 ACRES=ANSWER(ENTRY)
      IF (ACRES.LE.AREA(STRATA)) GO TO 250
      WRITE(6,245) STRATA, AREA(STRATA)
  245 FORMAT(7H STRATA,I3,9H HAS ONLY,F7.0,12H ACRES IN IT)
      GO TO 260
  250 METHOD=WORD-3
      ALTER=MODIFY(METHOD,STRATA)-ACRES
      SPENT(WORD)=SPENT(WORD)-ALTER*PRICE(WORD)
      MODIFY(METHOD,STRATA)=ACRES+0.1
  260 CONTINUE
      GO TO 170
C
C F I R E  S T A T I O N S
C
  300 WRITE(6,305)
  305 FORMAT(2H8:)
      CALL REPLY(ARGUE2,METHOD,ANSWER,GOTTEN)
      IF(METHOD.EQ.0) GO TO 160
      IF (GOTTEN.GT.0 .AND. (GOTTEN/2)*2 .EQ. GOTTEN) GO TO
     *    (330,370),METHOD
      WRITE(6,315)
```

```
  315 FORMAT(20H COORDINATES MISSING)
      GO TO 300
C
C FIRFSTATION DELETER
C
  330 DO 360 ENTRY=2,GOTTEN,2
      STORE=UNITS(TOWERS)
      IF(STORE.EQ.0) GO TO 352
      DO 350 J=1,STORE
      IF (LOCALE(X,J).NE.ANSWER(ENTRY-1) .OR.
     *    LOCALE(Y,J).NE.ANSWER(ENTRY)) GO TO 350
      IF(AGE(J).GT.4 .OR. AGE(J).LT.1) GO TO 340
      WRITE(6,335) LOCALE(X,J), LOCALE(Y,J)
  335 FORMAT(11H STATION AT,I4,1H,,I4,15H WAS NOT DELETED)
      GO TO 360
  340 LOCALE(X,J)=LOCALE(X,STORE)
      LOCALE(Y,J)=LOCALE(Y,STORE)
      UNITS(TOWERS)=STORE-1
      GO TO 360
  350 CONTINUE
  352 WRITE(6,355) ANSWER(ENTRY-1),ANSWER(ENTRY)
  355 FORMAT(11H STATION AT,F4.0,1H,,F4.0,15H DOES NOT EXIST)
  360 CONTINUE
      GO TO 300
C
C FIRESTATION ADDER
C
  370 DO 380 ENTRY=2,GOTTEN,2
      IF (ANSWER(ENTRY-1).LE.100.AND.ANSWER(ENTRY).LE.100.AND.
     *    ANSWER(ENTRY-1).GE.1.AND.ANSWER(ENTRY).GE.1) GO TO 378
      WRITE(6,375) ANSWER(ENTRY-1), ANSWER(ENTRY)
  375 FORMAT(12H STATION AT ,F4.0,1H,,F4.0,13H OUISIDE YOUR,  24H DISTRI
     1CT, WAS NOT ADDED)
      GO TO 380
  378 STORE=UNITS(TOWERS)+1
      IF(STORE.GT.10) CALL EXIT
      LOCALE(X,STORE)=ANSWER(ENTRY-1)
      LOCALE(Y,STORE)=ANSWER(ENTRY)
      UNITS(TOWERS)=STORE
      AGE(STORE)=0
  380 CONTINUE
      GO TO 300
C
C INPUT VALUE AT RISK OR FIRE HISTORY DECISIONS
C
  390 WRITE(6,395)
  395 FORMAT(27H-   F I R E   H I S T O R Y// 18H      THE DISTRICT,59H
     1HAS SOME HOT AREAS.  THE LOGGING OPERATION LEAVES/ 61H AROUND 2000
     2 ACRES OF SLASH PER YEAR, CONCENTRATED IN STRATAS,9H 2, 7 AND/ 42H
     3 8.  THE OPERATION IN STRATA 7 STARTS AS MANY AS,21H 20 FIRES PER
     4YEAR IN/ 36H OLD SLASH IF NOT MODIFIED TO REDUCE,29H THE HAZARD.
     5THE RAILROAD IS/ 26H ANOTHER DANGER TO STRATAS,43H 2 AND 7.  THE 3
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     6OLDENVIEW SUBDIVISION HAS A/ 55H DUMP IN STRATA 6 AND IS NOTORIOUS
     7 FOR BREAKING BURNING,7H PERMIT/ 41H REGULATIONS.  THE CAMPERS AR
     8 RECREATION,24H SEEKERS IN STRATA 9 ARE/ 31H OFTEN OBLIVIOUS TO TH
     9E DANGERS,23H OF THE MISUSE OF FIRE.///////)
      GO TO 398
  396 WRITE(6,397) ((STRATA,VALUE(STRATA)),STRATA=1,10)
  397 FORMAT(22H- VALUE AT RISK SURVEY// 20H STRATA   $$/ACRES ,13H  DE
     1SCRIPTION/ I3,F7.0,16HROW CROPS & WOOD,4HLOTS/ I3,F7.0,17H HARDWOO
     2D QUALITY/ I3,F7.0,10H ROW CROPS/ I3,F7.0,13H LUXURY HOMES/ I3,F7.
     30,27H LOW TO MEDIUM INCOME HOMES/ I3,F7.0,19H EROSION PROTECTION/
     4I3,F7.0,17H MERCHANTABLE SAW,6HTIMBER/ I3,F7.0,22H PLANTATIONS(1-3
     50 YRS)/ I3,F7.0,25H SUMMER HOMES & SAWTIMBER/ I3,F7.0,24H MARGINAL
     6LY MERCHANTABLE,10H SAWTIMBER///////)
  398 SPENT(WORD)=PRICE(WORD)
      GO TO 170
C
C F I R E B R E A K S
C
  400 WRITE(6,405)
  405 FORMAT(2H$:)
      CALL REPLY(ARGUE2,METHOD,ANSWER,GOTTEN)
      IF(METHOD.EQ.0) GO TO 170
      IF (GOTTEN.GT.0) GO TO 430
      WRITE(6,417)
  417 FORMAT(21H BLOCK NUMBER MISSING)
      GO TO 400
  430 DO 450 ENTRY=1,GOTTEN
      BLOCK=ANSWER(ENTRY)+0.1
      IF (BLOCK.GE.11 .AND. BLOCK .LE. 20) GO TO 440
      WRITE(6,435) BLOCK
  435 FORMAT(8H BLOCK #,I3,23H INCORRECT, NOT ENTERED)
      GO TO 450
  440 MODIFY(3,BLOCK)=METHOD
      SPENT(WORD)=SPENT(WORD)+PRICE(BLOCK)*(-1)**METHOD
  450 CONTINUE
      GO TO 400
C
C  GIVE DETAILS FOR PARTICULAR STRATA AND CLASS
C
  460 IF (TIMER.GT.0) GO TO 470
      WRITE(6,465)
  465 FORMAT(33H NO FIRES HAVE BEEN GENERATED YET)
      GO TO 120
  470 IF (GOTTEN.GT.0) GO TO 480
      WRITE(6,475)
  475 FORMAT(31H ENTER IN FORM: DETAILS, STRATA)
      GO TO 120
  480 DO 520 ENTRY=1,GOTTEN
      STRATA=ANSWER(ENTRY)+.1
      IF (STRATA.GE.1 .AND. STRATA.LE.10) GO TO 490
      WRITE(6,485) STRATA
  485 FORMAT(19H THERE IS NO STRATA,I3)
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      GO TO 120
  490 WRITE(6,495) STRATA
  495 FORMAT(25H&MINIMUM CLASS FOR STRATA,I3,1H:)
      CALL REPLY(ARGUE3,CLASS,DUMMY,NUMBER)
      IF (CLASS .EQ. 0) GO TO 490
      NUMBER=TOTAL(STRATA)
      IF (NUMBER.GT.0) GO TO 500
      WRITE(6,497) STRATA
  497 FORMAT(19H NO FIRES IN STRATA,I3,10H THIS YEAR)
      GO TO 520
  500 LIMIT=MAX(CLASS)
      WRITE(6,501) STRATA
  501 FORMAT(//7H STRATA,I3,/28H   X    Y     AREA     COST+LOSS)
      DO 510 FIRE=1,NUMBER
      IF (BURNED(STRATA,FIRE).LT. LIMIT) GO TO 510
C     OUTPUT DETAILED INFORMATION BY FIRE
      WRITE(6,505) XSTART(STRATA,FIRE),YSTART(STRATA,FIRE)
     *             ,BURNED(STRATA,FIRE),DAMAGE(STRATA,FIRE)
  505 FORMAT(I4,1H,,I3,F8.2,F10.0)
  510 CONTINUE
  520 CONTINUE
      GO TO 120
C      ************************************************************
C
C     START MAIN PART OF PROGRAM
C
C     ************************************************************
C     CHECK BUDGET
C
  600 IF(SKIP.EQ.YES) GO TO 603
      WRITE(6,601) (SPENT(I),I=1,5)
  601 FORMAT(17HOSTRATEGY SUMMARY/33H BILLBOARDS   CONTACTS   RADIO A.
     1    ,22H   BURNING   CRUSHING / 5F11.0)
      WRITE(6,602) (SPENT(I),I=6,10)
  502 FORMAT(47H FIREBREAKS  F.STATIONS F.HISTORY  VAL AT RISK ,10HPROJE
     1CTION/ 5F11.0)
  603 IF (BUDGET.LE. 500000.) GO TO 610
      WRITE(6,605) BUDGET
  605 FORMAT(13HOBUDGET OF $ ,F8.0,27H REJECTED; CUT SPENDING TO , 21H$5
     100,000 AND RESUBMIT///////)
      GO TO 120
  610 DO 609 STRATA=1,10
      TOTAL(STRATA)=0
      DO 609 CLASS=A,E
       TDAMAG(STRATA,CLASS)=0.
       TSIZE(STRATA,CLASS)=0.
  609 CONTINUE
      GTOTAL=BUDGET
      EXTENT=0.0
      SPENT(8)=0.
      SPENT(9)=0.
      SPENT(10)=0.
```

```
      IF (UNITS(TOWERS) .EQ. 0) GO TO 630
      STORE=UNITS(TOWERS)
      DO 620 J=1,STORE
      AGE(J)=AGE(J)+1
  620 CONTINUE
  630 TIMER=TIMER+1
C
C     CALCULATE FIRE PROBABILITIES
C
      DO 660 SOURCE=1,20
      SUM=0.0
      DO 640 PLAN=1,3
      SUM=SUM+EFFECT(SOURCE,PLAN)*UNITS(PLAN)
  640 CONTINUE
      DO 650 PLAN=4,5
      IF(HAZARD(SOURCE).EQ.0.0) GO TO 650
      SUM=SUM+EFFECT(SOURCE,PLAN)*(MODIFY(PLAN-3,SOURCE)/
     *    HAZARD(SOURCE))
  650 CONTINUE
      IF(MODIFY(3,SOURCE).EQ.DEL) GO TO 653
      SUM=SUM+EFFECT(SOURCE,6)*0.3
  653 FIRES(SOURCE)=EXPECT(SOURCE)*AMAX1(0.01,1.-SUM)
  660 CONTINUE
C
C      PRINT OPTIONAL MATRIX OF EXPECTED FIRES IN EACH
C      STRATA AND FROM EACH BLOCK.  OBTAINED WITH KEY
C      WORDS INSTRUCTOR AND EXPECT.
C
      IF(MATRIX.EQ.NO) GO TO 664
      WRITE(6,661) (SOURCE,SOURCE=1,10),(FIRES(SOURCE),SOURCE=1,10)
  661 FORMAT(25H0   EXPECTED FIRES MATRIX/ 7HOSTRATA,I3,9I4,/7H EXPECT,1
     10F4.0)
      WRITE(6,662) (SOURCE,SOURCE=11,20),(FIRES(SOURCE),SOURCE=11,20)
  662 FORMAT(7HOBLOCK ,I3,9I4,/7H EXPECT,10F4.0)
C
C     START FIRE GENERATION
C
  664 MARK=1
      ICOUNT=0
      XSIZE=0.
      FSIZE=0.
  665 DO 920 SOURCE=1,20
      NFIRES=GAUSS(ISEED,0.6*FIRES(SOURCE),FIRES(SOURCE))+0.5
      IF (MARK.EQ.ONE) GO TO 670
      NFIRES=FIRES(SOURCE)+0.5
  670 IF (NFIRES.EQ.0) GO TO 920
      DO 910 FIRE=1,NFIRES
C
C       DETERMINE X,Y COORDINATES OF FIRE
C
      XCOORD=BOUND(WEST,SOURCE)
      XCOORD=XCOORD+URAND(ISEED)*(BOUND(EAST,SOURCE)-XCOORD)
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      YCOORD=BOUND(NORTH,SOURCE)
      YCOORD=YCOORD+URAND(ISEED)*(BOUND(SOUTH,SOURCE)-YCOORD)
      GAP=1.E10
      STORE=UNITS(TOWERS)
      IF(STORE.EQ.0) GO TO 690
      DO 680 I=1,STORE
      GAP=AMIN1(GAP,FLOAT(IABS(LOCALE(X,I)-XCOORD)+IABS(LOCALE(Y,I)-
     *YCOORD)))
  680 CONTINUE
C
C       CALCULATE SIZE FROM GAMMA DISTRIBUTION
C
C*************REDUCE SIZE BY CONTROL FACTOR F(GAP)
  690 ALPHA=SHAPE(SOURCE)
      BETA=SCALE(SOURCE)
      SIZE=GAM(BETA,ALPHA,ISEED)
      IF(MARK.EQ.TEN) SIZE=ALPHA*BETA
      IF(SIZE.LT.0.01) GO TO 910
      XSIZE=XSIZE+SIZE
      SIZE=SIZE*AMIN1(0.015*GAP+0.2,1.0)
      FSIZE=FSIZE+SIZE
      LOSS=0.0
      ICOUNT=ICOUNT+1
      IF(ICOUNT.EQ.151) GO TO 921
      IF (SIZE.GT.0.25) GO TO 692
      CLASS=A
      COST=100.
      GO TO 880
  692 COST=500.
      IF (SIZE.GT.10.0) GO TO 700
      CLASS=B
      GO TO 880
  700 CLASS=C
      LOSS=SIZE*VALUE(SOURCE)
      TOP=YCOORD
      BOTTOM=YCOORD
      LEFT=XCOORD
      RIGHT=XCOORD
      IF (SIZE.LT.100.0) GO TO 710
      CLASS=D
      IF(SIZE.GT.299.0) CLASS=E
      COST=100.0*SIZE
      NCELLS=SIZE/160. +1.0
C
C       IF FIRE IS LARGE ENOUGH, SPREAD TO ADJACENT CELLS
C
      TOP=YCOORD-NCELLS/4.+1.0
      RIGHT=XCOORD+NCELLS/6.+1.0
      BOTTOM=YCOORD+(NCELLS+4)/7.+1.0
      LEFT=XCOORD-(NCELLS+4)/6.+1.0
      REMAIN=SIZE
  710 DO 870 I=TOP,BOTTOM
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      DO 860 J=LEFT,RIGHT
      IF (MARK.EQ.TEN) GO TO 840
C
C     CHECK FOR DAMAGE TO "NOTABLES" HOMES
C
      DO 740 K=1,5
      IF(J.NE.HOME(X,K) .OR. I.NE.HOME(Y,K)) GO TO 740
      IF(USED(K).EQ.YES) GO TO 740
      USED(K)=YES
      WRITE(7,715)
  715 FORMAT(47H0 AP DATELINE BELLYVILLE    N E W S   F L A S H)
      LOSS=LOSS+30000.
      GO TO (721,723,725,727,729),K
  721 WRITE(7,722) J,I
  722 FORMAT(51H0      NELSON ONASSIFELLER, PRESIDENT OF THE MASSIVE,3H M
     1AMMOTH/ 47H CORPORATION, WAS MOMENTARILY AGHAST TODAY WHEN,16H HE
     2WAS INFORMED/ 38H THAT HIS NEW VACATION RETREAT LOCATED,15H AT COO
     3RDINATES/ 2I3,36H IN THE BEAVER BELLY FOREST DISTRICT,19H HAD BEEN
     4 DESTROYED/ 33H IN A WILDFIRE.  RUMORS HAVE BEEN,26H HEARD THAT A
     5VENDETTA HAS/ 23H BEEN PLANNED AGAINST A,26H CERTAINED UNNAMED RAN
     6GER./////////)
      GO TO 740
  723 WRITE(7,724) J,I
  724 FORMAT(51H0      MS. PRISCILLA TEACUP, CHAIRWOMAN OF THE LOCAL,18H
     1CHAPTER OF THE/ 36H LEAGUE OF WOMEN VOTERS, UNLEASHED A,25H TIRADE
     2 AGAINST THE LOCAL/ 31H RANGER IN A THREE HOUR MESSAGE,32H PHONED
     3INTO THIS OFFICE EARLIER,/18H TODAY.  THE WORDS,40H NEGLIGENT, I
     4MPOTANT, AND STUPID WERE,/12H USED FREELY,10H AND OFTEN/ 41H
     5IT WAS ALSO LEARNED THAT MS. TEACUPS,20H HOUSE WAS BURNED AT/ 12H
     6COORDINATES,2I3,10H DURING A ,23H SERIOUS WILDFIRE YESTERDAY./////
     7//)
      GO TO 740
  725 WRITE(7,726) J,I
  726 FORMAT(53H      THE GOVERNOR TODAY LAUNCHED A CAMPAIGN TO FORCE,1
     1H THE ADOPTION OF/ 36H SCREENING POLICIES FOR FIRE CONTROL,24H MAN
     2AGEMENT PERSONNEL ON/ 27H NATIONAL, STATE, AND LOCAL,43H LEVELS.
     3THE ACTION FOLLOWED THE NEWS THAT/ 10H THE LOCAL,57H AGENT ON THE
     4BEAVER BELLY DISTRICT ALLOWED THE GOVERNORS/ 33H NEW HUNTING LODGE
     5 AT COORDINATES,2I3,20H TO BURN DOWN DURING,14H A FOREST FIRE/ 16H
     6 FIRE YESTERDAY./////////)
      GO TO 740
  727 WRITE(7,728) J,I
  728 FORMAT(49H      IT WAS ANNOUNCED TODAY IN THE NEW YORK HEAD,20HQUA
     1RTERS OF THE GIRL/ 34H SCOUTS OF AMERICA THAT THEIR GIRL,34H SCOUT
     2 LEADERS JUNGLE SURVIVAL AND/ 15H ANTI-CHAUVINISM,35H TRAINING FAC
     3ILITIES AT COORDINATES,2I3,10H NEAR CAMP,/53H MOAHOPTWATPA ON THE
     4BEAVER BELLY DISTRICT WAS BURNED,13H DOWN.  IT IS/ 38H RUMORED THA
     5T THE LOCAL AGENT WAS SEEN,27H LAUGHING AS 46 PROSPECTIVE/ 23H LEA
     6DERS TOOK REFUGE IN,35H NEARBY SPRINGFED LAKE KITCHIKWAMI./ 18H
     7  REPRISALS ARE,10H EXPECTED./////////)
      GO TO 740
  729 WRITE(7,730) J,I
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  730 FORMAT(55H      IT WAS LEARNED TODAY THAT KANIPEEKI NUDIST COLONY,
     115H AT COORDINATES/ 2I3,37H WAS EVACUATED IN AN EMERGENCY ACTION,2
     24H TO PREVENT LOSS OF LIFE/ 30H DUE TO A THREATENING WILDFIRE,39H.
     3  UNFORTUNATELY THE COLONY BURNED AS A/ 19H PREVIOUSLY SECURE,44H
     4FIRE LINE WAS BREACHED BECAUSE ALL OF THE FIRE-/ 58H FIGHTERS WERE
     5 FACING THE WRONG WAY AS THE FIRE APPROCHED.///////)
  740 CONTINUE
C
C       ACCUMULATE LOSSES
C
  840 IF(SIZE.LT.161.0) GO TO 880
      DO 850 STRATA=1,10
      IF (I.GT.BOUND(SOUTH,STRATA).OR.J.GT.BOUND(EAST,STRATA).OR.
     *    I.LT.BOUND(NORTH,STRATA).OR.J.LT.BOUND(WEST,STRATA))GO TO 850
      LOSS=LOSS+AMIN1(AREA(STRATA),160.)*VALUE(STRATA)
      REMAIN=AMAX1(0.0,REMAIN-160.)
      IF(REMAIN.EQ.0.) GO TO 880
  850 CONTINUE
  860 CONTINUE
  870 CONTINUE
C
C       IDENTIFY STRATA OF START
C
  880 STRATA=SOURCE
      IF(STRATA.LE.10) GO TO 900
      STRATA=IDENT(SOURCE-10)
C
C     INFORMATION STORAGE
C
  900 GTOTAL=GTOTAL+COST+LOSS
      EXTENT=EXTENT+SIZE
      IF(MARK.EQ.TEN)GO TO 910
      NUMBER=TOTAL(STRATA)+1
      TOTAL(STRATA)=NUMBER
      DAMAGE(STRATA,NUMBER)=COST+LOSS
      BURNED(STRATA,NUMBER)=SIZE
      XSTART(STRATA,NUMBER)=XCOORD
      YSTART(STRATA,NUMBER)=YCOORD
      TDAMAG(STRATA,CLASS)=TDAMAG(STRATA,CLASS)+COST+LOSS
      TSIZE(STRATA,CLASS)=TSIZE(STRATA,CLASS)+SIZE
  910 CONTINUE
  920 CONTINUE
  921 IF (MARK.EQ.TEN) GO TO 1120
      FINALC=FINALC+GTOTAL
      FINALA=FINALA+EXTENT
      FINALN=FINALN+ICOUNT
C
C       Y E A R L Y   S U M M A R Y
C
      WRITE(6,923)
  923 FORMAT(///5X,24HYEARLY COST+LOSS SUMMARY/)
      IF(TIMER.EQ.1) WRITE(6,924)
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  924 FORMAT(38H TOTAL FIRES PER STRATA IN PARENTHESES)
      WRITE(6,925)
  925 FORMAT(1H ,10X,5HCLASS/12H STRATA    A,6X,1HB,6X,1HC,8X,1HD,9X,1HE
     1)
      DO 960 STRATA=1,10
      DO 940 CLASS=A,E
      LAST=6-CLASS
      IF(TDAMAG(STRATA,LAST).GT.0.0) GO TO 950
  940 CONTINUE
      GO TO 960
  950 WRITE(6,955) STRATA,TOTAL(STRATA)
     *,(TDAMAG(STRATA,CLASS),CLASS=A,LAST)
  955 FORMAT(1H ,I3,1H(,I2,1H),F5.0,F7.0,F9.0,2F10.0)
  960 CONTINUE
      SIZE=FSIZE/AMAX0(1,ICOUNT)
      WRITE(6,975) ICOUNT,EXTENT,GTOTAL,SIZE
  975 FORMAT(15HOTOTALS: FIRES=,I3,10H, ACREAGE=,F7.0,/ 12H COST+LOSS=$,
     1F10.0,15H, AV. FIRE SIZE,F6.2,6H ACRES/////)
      IF(INIT.EQ.NO) GO TO 1000
      SIZE=XSIZE/AMAX0(1,ICOUNT)
      WRITE(6,985) SIZE
  985 FORMAT(14H AV INIT SIZE=,F6.2/)
C
C C O M M E N T  S E L E C T O R
C
 1000 RANDOM=URAND(ISEED)
      IF (GTOTAL.GT.CUT(1)) GO TO 1030
      I=IT(P1,5,RANDOM)
      GO TO (1001,1003,1005,1007,1009),I
 1001 WRITE(7,1002)
 1002 FORMAT(52H      CONGRATULATIONS, THE STATE JUNIOR RANGERS CLUBS,14H
     1 HAVE SELECTED/ 35H YOU AS THEIR HONORARY "FIRESTOPPER,32H SUPERST
     2AR OF THE YEAR" FOR YOUR/ 32H UNPRECEDENTED SUCCESS,44H IN PREVENT
     3ING AND CONTROLLING FIRES ON THE / 7H BEAVER,26H BELLY DISTRICT TH
     4IS YEAR.///////)
      GO TO 1020
 1003 WRITE(7,1004) ICOUNT
 1004 FORMAT(55H      THE UNITED FRIENDS OF S. T. BEAR HAVE UNANIMOUSLY,
     18H ELECTED/ 49H YOU AS THIS YEARS NOMINEE TO THE S. T. BEAR FIRE,1
     29H PREVENTION HALL OF/ 27H FAME.  YOUR RECORD OF ONLY,I3,5H FIRES,
     329H ON THE BEAVER BELLY DISTRICT,/25H THIS YEAR HAS BEEN NAMED,36H
     4 AS THE PRIMARY CONTRIBUTING FACTOR.///////)
      GO TO 1020
 1005 WRITE(7,1006)
 1006 FORMAT(50H      CONGRATULATIONS, BECAUSE OF YOUR OUTSTANDING,19H P
     1ERFORMANCE IN THE/ 34H AREA OF MANGEMENT DECISION MAKING,34H ON TH
     2E BEAVER BELLY DISTRICT THIS/ 15H YEAR, THE LOCAL,50H LADIES AID S
     3OCIETY HAS REQUESTED THAT YOUR BE THE/ 49H GUEST OF HONOR AT THEIR
     4 ANNUAL BANQUET.  YOU ARE,20H REQUESTED TO MAKE A/ 25H 20 MINUTE S
     5PEECH ON "HOW,36H MUDDLING THROUGH CAN WORK FOR YOU".///////)
      GO TO 1020
 1007 WRITE(7,1008) GTOTAL
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1008 FORMAT(33H TO: RANGER,BEAVER BELLY DISTRICT/ 16H FROM: OFFICE OF,1
    14H THE PRESIDENT/ 40H     I WISH TO EXTEND TO YOU MY PERSONAL,2
    2"WELL DONE" FOR YOUR OUT-/ 25H STANDING CONTRIBUTION TO,11H BALANC
    3ING THE NATIONAL BUDGET BY HOLDING/ 11H THE BEAVER,31H BELLY COST
    4PLUS LOSS TO ONLY $,F7.0,18H THIS FISCAL YEAR./ 56H THIS EFFICIENC
    5Y IS EVIDENCE THAT YOU CAN DO BETTER WITH,9H LESS, SO/ 40H YOUR ST
    6AFF WILL BE REDUCED ACCORDINGLY.///////)
     GO TO 1020
1009 WRITE(7,1010) GTOTAL
1010 FORMAT(34H TO: RANGER, BEAVER BELLY DISTRICT/ 11H FROM: HEAD,33H I
    1NSPECTOR, REGIONAL ACCOUNTING OFFICE/ 9H     YOUR,57H OUTSTANDING
    2BUDGET AND DAMAGE STATISTICS FOR THIS FISCAL,/32H YEAR DESERVE SOM
    3LATION.  ONLY $,F7.0,14H IN TOTAL COST,11H PLUS LOSS / 41H IS SO E
    4XTRAORDINARY IN FACT, THAT WE ARE,25H GOING TO DO A FULL AUDIT/ 25
    5H OF ALL OF YOUR TRANSACTIONS,40H AND DAMAGE APPRAISALS FOR THE PA
    6ST FIVE/ 7H YEARS./ 51H     IT IS HOPED THAT THIS EVALUATION WILL
    7 PROVIDE/ 53H GUIDELINES FOR OTHER ASPIRING FIRE CONTROL MANAGERS.
    8///////)
1020 IF (GTOTAL.GT.200000.) GO TO 110
     WRITE(7,1025)
1025 FORMAT(55H CONABUNGA! YOU WIN THE JUNIOR RANGER OF THE YEAR AWARD/
    1   35H YOU ARE THE LUCKIEST MUDDLER ALIVE)
     GO TO 110
1030 IF(GTOTAL.LT.CUT(2)) GO TO 110
     I=IT(P2,5,RANDOM)
     WRITE(7,1031)
1031 FORMAT(23H- UPI WIRESERVICE FLASH/ 21H  DATELINE BELLYVILLE)
     GO TO (1032,1034,1036,1038,1040),I
1032 WRITE(7,1033) ICOUNT
1033 FORMAT(51H      THE ENVIRONMENTAL PROTECTION AGENCY ANNOUNCED,15H
    1THAT DUE TO THE/ I4,55H FIRES ON THE BEAVER BELLY DISTRICT THIS YE
    2AR THAT THEY,7H HAD TO/ 47H DESIGN A NEW SCALE FOR THEIR NUMERICAL
    3X.  THEY,18H HAVE INITIATED AN/ 39H INVESTIGATION INTO THE FIRE PR
    4EVENTION,29H AND CONTROL METHODS EMPLOYED/ 20H SO THAT APPROPRIATE
    5,46H LEGISLATION MAY BE ENACTED TO PREVENT IT FROM/ 5H EVER,17H HA
    6PPENING AGAIN.///////)
     GO TO 1050
1034 WRITE(7,1035) GTOTAL
1035 FORMAT(51H     THE REGIONAL ACCOUNTING OFFICE ANNOUNCED TODAY,18H
    1THAT A FULL AUDIT/ 36H OF THE FIRE MANAGEMENT ORGANIZATION,35H WIL
    2L BE CONDUCTED IN AN ATTEMPT TO/ 13H DISCLOSE THE,44H SUSPECTED MI
    3SALLOCATIONS THAT RESULTED IN $,F10.0/ 55H COST PLUS LOSS ON THE B
    4EAVER BELLY DISTRICT THIS YEAR.///////)
     GO TO 1050
1036 WRITE(7,1037) ICOUNT
1037 FORMAT(53H GOVERNMENT SOURCES ANNOUNCED TODAY THAT THE PENTAGON,10
    1H WILL SEND/ 44H A TEAM OF INVESTIGATORS TO THE BEAVER BELLY,21H D
    2ISTRICT TO UNCOVER THE,/17H REASONS FOR THE ,I3,6H FIRES,12H THAT
    3OCCURRED THERE LAST YEAR.  THEY HOPE,/11H TO USE THE,53H INFORMATI
    4ON TO DEVELOP NEW GUIDELINES FOR INCENDIARY/ 18H GUERRILA WARFARE.
    5///////)
     GO TO 1050
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 1038 WRITE(7,1039)
 1039 FORMAT(45H      THE WHITE HOUSE ANNOUNCED TODAY THAT THE,29H VICE
     1PRESIDENT WILL/ 35H OVERFLY THE DECIMATED BEAVER BELLY,25H DISTRI
     2 TOMORROW.  HE IS/ 27H CONSIDERING DECLARING IT A,43H DISASTER ARE
     3A BECAUSE OF THE RECENT SERIES/ 9H OF FIRES,55H THAT OCCURRED AS A
     4 RESULT OF GROSS MISMANAGEMENT BY AN/ 15H UNNAMED RANGER.///////)
       GO TO 1050
 1040 WRITE(7,1041) ICOUNT
 1041 FORMAT(46H      A COALITION OF THE SIERRA CLUB AND OTHER,23H ENVIR
     1ONMENTAL INTEREST/ 28H GROUPS HAVE ANNOUNCED PLANS,41H TO PICKET A
     2LL OF THE DISTRICT OFFICES IN/ 11H THE REGION,56H UNTIL THE RANGER
     3 OF THE BEAVER BELLY DISTRICT COMES OUT/ 31H OF THE HILLS AND EXPL
     4AINS THE ,I3,21H WILDFIRES THAT SWEPT,13H HIS DISTRICT/ 40H IN AN
     5UNPRECEDENTED ECOLOGICAL DISASTER,11H LAST YEAR.///////)
 1050 IF (GTOTAL.LT.CUT(3)) GO TO 110
       RANDOM=URAND(ISEED)
       I=IT(P3,3,RANDOM)
       WRITE(7,1051)
 1051 FORMAT(34HOTO: RANGER, BEAVER BELLY DISTRICT/13H FROM: FOREST,29H
     1SUPERVISOR   P E R S O N A L)
       IF(CHANCE.GT.3) GO TO 1080
       CHANCE=CHANCE+1
       GO TO (1052,1054,1056),I
 1052 WRITE(7,1053)
 1053 FORMAT(52HO      THE LOCAL CONGRESSMEN ARE ENRAGED BECAUSE SOME ,14
     1H%*/#& FORESTER/ 39H IS BURNING UP THEIR DISTRICT. TRANSFER,22H PR
     2OCEEDINGS HAVE BEEN/ 29H INITIATED, DESTINATION NONE.///////)
       GO TO 110
 1054 WRITE(7,1055)
 1055 FORMAT(52HO      IT HAS BEEN DECIDED THAT DUE TO YOUR OVERWHELM ,4H
     1ING / 54H EFFICIENCY AT STARTING FIRES, YOU WILL BE TRANSFERRED, 12
     2H TO NORTHERN/ 43H ALASKA WHERE YOU WILL GIVE AID AND COMFORT, 15H
     3TO THE ESKIMOS.///////)
       GO TO 110
 1056 WRITE(7,1057)
 1057 FORMAT(52HO      THE SIERRA CLUB AND THE LUMBERMANS ASSOCIATION,14H
     1 HAVE FINALLY SEEN/ 34H EYE TO EYE ON AN ISSUE: THAT YOUR,33H PERF
     2ORMANCE AS A FIRE MANAGER IS/ 21H WELL SUITED TO A 95%,49H WATERY G
     3OVERED DISTRICT IN THE OKEEFENOKEE SWAMP.//////)
       GO TO 110
 1080 WRITE(6,1085) TIMER,FINALC
 1085 FORMAT(42H      YOU HAVE HAD 3 WARNINGS OVER THE PAST,I2,10H YEARS
     1AND,14H YOUR DISTRICT/ 11H HAS LOST $,F10.0,25H IN THAT PERIOD.  TR
     2ANSFER,21H PROCEEDINGS WILL NOT/ 29H BE NECESSARY, YOU ARE FIRED!!
       GO TO 1310
C
C  CALCULATE LONG TERM PROJECTION
C
C      THIS SECTION RETURNS THE PROGRAM THROUGH THE FIRE GENERATION AND
C      DAMAGE CALCULATION SECTIONS WITHOUT PRINTING ANY RESULTS. THE TEN
C      YEAR AVERAGES ARE CALCULATED AND PRINTED HERE.
C
```

```
 1100 GTOTAL=0.0
      EXTENT=0.0
      MARK=TEN
      DO 1120 YEAR=1,10
      GO TO 665
 1120 CONTINUE
      GTOTAL=GTOTAL/10.0+BUDGET
      EXTENT=EXTENT/10.
      WRITE(6,1125) GTOTAL,EXTENT
 1125 FORMAT(49HOEXPECTED YEARLY AVERAGES FROM 10 YEAR PROJECTION/ 12HCO
     1ST+LOSS= $,F10.0,11H   ACREAGE=,F8.0//////)
      SPENT(WORD)=PRICE(WORD)
      GO TO 170
C      **********************************************************************
C
C      I N S T R U C T O R S   C O M M A N D S
C
C       SIZE - OUTPUTS ORIGINAL FIRE SIZE
C       CLEAN - REMOVES ALL STRATEGIES
C       EXPECTED - MATRIX OF EXPECTED NUMBER OF FIRES
C       NOEXPECT - PREVENTS MATRIX ABOVE
C       NOBUDGET - PREVENTS BUDGET SUMMARY
C       BUDGET - OUTPUTS BUDGET SUMMARY
C       CUTOFF N NN - SETS COMMENT CUT N AT NN
C
C      **********************************************************************
 1200 WRITE(6,1205)
 1205 FORMAT(2H$*)
      CALL REPLY(ARGUE4,WORD,ANSWER,GOTTEN)
      IF(WORD.EQ.0) GO TO 120
      GO TO(1210,1220,1230,1240,1250,1260,1270,120),WORD
 1210 INIT=YES
      WRITE(6,1215)
 1215 FORMAT(4H *OK)
      GO TO 1200
 1220 DO 1225 I=1,20
      IF(I.LT.8) UNITS(I)=0
      IF(I.LT.11) SPENT(I)=0.0
      MODIFY(1,I)=0
      MODIFY(2,I)=0
      MODIFY(3,I)=1
 1225 CONTINUE
      CHANCE=0
      WRITE(6,1215)
      GO TO 1200
 1230 MATRIX=YES
      WRITE(6,1215)
      GO TO 1200
 1240 MATRIX=NO
      WRITE(6,1215)
      GO TO 1200
 1250 SKIP=YES
```

```
      WRITE(6,1215)
      GO TO 1200
 1260 SKIP=NO
      WRITE(6,1215)
      GO TO 1200
 1270 IF((GOTTEN/2.)*2.NE.GOTTEN) GO TO 1200
      DO 1290 ENTRY=1,GOTTEN,2
      I=ANSWER(ENTRY)+0.5
      CUT(I)=ANSWER(ENTRY+1)
 1290 CONTINUE
      WRITE(6,1215)
      GO TO 1200
 1300 IF(TIMER.EQ.0) GO TO 1310
      FINALC=FINALC/TIMER
      FINALN=FINALN/TIMER
      FINALA=FINALA/TIMER
      WRITE(6,1315) FINALN,FINALA,FINALC
 1315 FORMAT(31H0 YEARLY AVERAGES FOR YOUR PLAY/ 9H NUMBER =,F4.0,6H FIR
     1ES/ 6H SIZE=,F6.0,6H ACRES,/ 13H COST+LOSS =$,F8.0)
 1310 WRITE(6,1350)
 1350 FORMAT(36H0THANK YOU FOR PLAYING FLASH FIRE II//)
      CALL EXIT
      END
      SUBROUTINE REPLY(LIST,WORD,ANSWER,GOTTEN)
C     VARIABLE      DEFINITION
C     ************************************************************
C     ALLOWD        THE NUMBER OF NUMBERS THAT MAY BE READ
C     ANSWER        AN ARRAY OF THE NUMBERS READ
C     BLANK         A LITERAL BLANK
C     COMMA         A LITERAL COMMA
C     DIGIT         AN ARRAY OF CHARACTERS LEGAL IN NUMBERS
C     DIGITS        THE NUMBER OF DIGITS IN A NUMBER
C     DONE          A SWITCH TO INDICATE THAT A WORD IS NOT A KEYWORD
C     EXP           THE EXPONENT FOR FRACTIONAL PARTS OF NUMBERS
C     FIRST         A SWITCH TO INDICATE A NEW WORD OR NUMBER
C     GOTTEN        THE NUMBER OF NUMBERS FOUND
C     LENGTH        THE LENGTH OF THE STRING READ IN
C     LIST          LIST OF KEYWORDS
C     WORD          THE KEYWORD INDEX NUMBER RETURNED
      INTEGER ALLOWD
     *       ,BLANK
     *       ,COMMA
     *     ,DIGIT(15)
     *       ,DIGITS
     *       ,EXP
     *       ,GOTTEN
     *       ,LIST(1)
     *       ,POINT
     *       ,SIGN
     *       ,STRING(80)
     *     ,SYMBOL(5)
     *       ,WORD
```

```
      REAL ANSWER(1)
      LOGICAL CHECK
     *       ,DONE
     *       ,FIRST
     *       ,KEY(20)
      EQUIVALENCE (BLANK,SYMBOL(4)),(COMMA,SYMBOL(5))
      DATA ALLOWD/10/
     *    ,DIGIT/1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,5*0/
     *    ,LENGTH/80/
     *    ,SYMBOL/1H.,1H-,1H+,1H ,1H,/
C
C     INITIALIZE SOME PARAMETERS
C
      WORD=0
      GOTTEN=0
      POINT=0
C
C     READ IN THE STRING OF CHARACTERS
C
   10 READ (5,15) (STRING(LETTER),LETTER=1,LENGTH)
   15 FORMAT(80A1)
C
C     DETERMINE THE FIRST NON-BLANK CHARACTER AFTER A BLANK OR COMMA
C
   20 FIRST=.TRUE.
   30 POINT=POINT+1
      IF(POINT.GT.LENGTH) RETURN
      IF(STRING(POINT).EQ.BLANK.OR.STRING(POINT).EQ.COMMA) GO TO 20
      IF(.NOT.FIRST) GO TO 30
      FIRST=.FALSE.
C
C     CHECK FOR A NUMBER
C
      DO 35 INDEX=1,5
      DIGIT(INDEX+10)=SYMBOL(INDEX)
35    CONTINUE
      DIGITS=0
      EXP=0
      NUMBER=0
      SIGN=1
50    DO 60 INDEX=1,15
      IF (STRING(POINT).EQ.DIGIT(INDEX)) GO TO (90,90,90,90,90,90,90
     1,90,90,90,80,70,80,120,120), INDEX
60    CONTINUE
      IF(DIGITS.GT.0) RETURN
      GO TO 200
70    SIGN=-1
80    DIGIT(INDEX)=DIGIT(1)
      GO TO 110
90    DIGITS=DIGITS+1
      IF (DIGITS.GT.1) GO TO 100
      DIGIT(12)=DIGIT(1)
```

```
      DIGIT(13)=DIGIT(1)
100   NUMBER=NUMBER*10+INDEX-1
      IF (DIGIT(11).NE.SYMBOL(1)) EXP=EXP+1
  110 POINT=POINT+1
      GO TO 50
120   GOTTEN=GOTTEN+1
      IF(GOTTEN.LE.ALLOWD) ANSWER(GOTTEN)=SIGN*NUMBER/10.**EXP
      GO TO 20
C
C     CHECK FOR A KEYWORD GIVEN THAT IT IS NOT A NUMBER
C
  200 DO 210 WORD=1,20
      KEY(WORD)=.TRUE.
  210 CONTINUE
      LETTER=0
  215 LETTER=LETTER+1
      DONE=.TRUE.
      WORD=0
      INDEX=1
      INCRE=-LIST(INDEX)
  220 INDEX=INDEX+LIST(INDEX)+INCRE
      WORD=WORD+1
       IF(WORD.GT.20)RETURN
      INCRE=1
      IF(LIST(INDEX).GT.0) GO TO 230
      WORD=0
      IF(DONE) GO TO 30
      POINT=POINT+1
      GO TO 215
  230 IF(LETTER.GT.LIST(INDEX)) GO TO 220
      IF(.NOT.KEY(WORD)) GO TO 220
      IF(STRING(POINT).EQ.LIST(INDEX+LETTER)) GO TO 240
      KEY(WORD)=.FALSE.
      GO TO 220
  240 DONE=.FALSE.
      IF(LETTER.NE.LIST(INDEX)) GO TO 220
      GO TO 30
      END
C
C     THIS SUBROUTINE SELECTS COMMENTS AT RANDOM
C     AND ALTERS THE PROBABILITIES OF SUBSEQUENT
C     SELECTION
C
C     P  IS AN ARRAY CONTAINING THE PROBABILITY
C        OF SELECTION FOR EACH COMMENT
C
C     N  IS THE NUMBER OF COMMENTS IN THE LIST
C
      FUNCTION IT(P,N,RANDOM)
      REAL P(1)
   10 SUM=0.0
      DO 20 I=1,N
```

```
      SUM=SUM+P(IT)
      IF(SUM.GE.RANDOM) GO TO 40
   20 CONTINUE
      DO 30 I=1,N
   30 P(I)=1./N
      GO TO 10
   40 P(IT)=0.0
      SUM=0.0
      DO 50 I=1,N
   50 SUM=SUM+P(I)
      IF(SUM.EQ.0.0) RETURN
      DO 60 I=1,N
   60 P(I)=P(I)/SUM
      RETURN
      END
C
C     THIS SUBROUTINE GENERATES THE NORMAL
C     DISTRIBUTION FOR THE NUMBER OF FIRES PER
C     STRATA, IT USES AS THE MEAN THE EXPECTED
C     NUMBER OF FIRES AS DETERMINED BY THE STRATEGY
C     INPUTS
C
      FUNCTION GAUSS(ISEED,STD,AMEAN)
      GAUSS=-6.0
      DO 10 I=1,12
      GAUSS=GAUSS+URAND(ISEED)
   10 CONTINUE
      GAUSS=AMEAN+GAUSS*STD
      RETURN
      END
      FUNCTION GAM(BETA,ALPHA,ISEED)
C
C     A GAMMA DISTRIBUTED RANDOM NUMBER GENERATOR
C
C     THE ALGORITHM, BASED ON JOHNK'S METHOD, IS TAKEN FROM RAND REPORT
C     R-641-PR, FEBRUARY 1971 BY M. B. BERMAN
C
C     BETA IS THE SCALE FACTOR
C     ALPHA IS THE SHAPE FACTOR
C
C     VALUES RETURNED HAVE MEAN OF ALPHA*BETA, VARIANCE OF ALPHA*BETA**2
      PROD=1.0
      K=ALPHA
      IF(K.LE.0) GO TO 20
      DO 10 I=1,K
      PROD=PROD*URAND(ISEED)
   10 CONTINUE
   20 GAM=-BETA*ALOG(PROD)
      D=ALPHA-FLOAT(K)
      IF(D.LE.0.0) RETURN
      A=1.0/D
      B=1.0/(1.0 - D)
```

```
   30 X=URAND(ISEED)**A
      Y=URAND(ISEED)**B+X
      IF(Y.GT.1.0) GO TO 30
      GAM=GAM-BETA*X/Y*ALOG(URAND(ISEED))
      RETURN
      END
```

BIBLIOGRAPHY

Bare, B. Bruce. 1971. The Purdue University Forest Management Game, University of Washington, Seattle, Washington.

Bentley, William R. and Warren V. Frick. 1972. Flash Fire: A Wild Fire Planning Game, Unpublished Paper, School of Natural Resources, University of Michigan, Ann Arbor, Michigan.

Bentley, William R. 1973. Lecture to Natural Resources 552, "Advanced Forest Management," School of Natural Resources, University of Michigan, Ann Arbor, Michigan.

Boocock, S. S. 1971. "Validity Testing of an Inter-Generational Relations Game," Proceedings, The National Gaming Council 10th Annual Symposium.

Countryman, David W. 1973. SNAFOR: A Computer Simulation for Use in Forest Resource Management Games. Unpublished Doctoral Dissertation, School of Natural Resources, University of Michigan, Ann Arbor, Michigan.

Crosby, John S. 1972. Conversation in planning meeting for FLASHFIRE revision. North Central Forest Experiment Station Fire Laboratory, Michigan State University, East Lansing, Michigan.

Crosby, John S. 1973. Appraisal of Forest Fire Damage and Values Protected from Forest Fires. Unpublished Report, Research Work Unit FS-NC-2101, North Central Forest Experiment Station Fire Laboratory, Michigan State University, East Lansing, Michigan.

Davis, Kenneth P. 1959. Forest Fire Control and Use. McGraw-Hill, New York.

Davis, J. B. and T. G. Storey, 1969. "Forest Fire Management Systems Research -- New Approaches to Old Problems," Unpublished Progress Report, Fire Management Systems Project, Pacific South West Forest and Range Experiment Station, Berkely, California.

I.B.M. 1972. IBM System/360 and System/370 FORTRAN IV Language. IBM Systems Reference Library, OS-44PS-DOS, IBM Corporation Programming Publications, New York.

Miller, David W. and Martin K. Starr. 1967. The Structure of Human Decisions. Prentice Hall, Englewood Cliffs, New Jersey.

Organick, E. I. 1967. A FORTRAN IV Primer. Addison-Wesley, Reading, Massachusetts.

Shackle, G. L. S. 1970. Expectation, Enterprise and Profit. George Allen and Unwin Ltd., London.

Simon, H. A. 1969. The Sciences of the Artificial. The M.I.T. Press, Cambridge, Massachusetts.

Streeby, L. L. 1969. "Foundations of an Improved Fire Damage Appraisal System." Unpublished report to the North Central Forest Experiment Station, The University of Wisconsin, Madison, Wisconsin.

Wagner, Harvey M. 1970. Principles of Management Science. Prentice Hall, Englewood Cliffs, New Jersey.